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AN EXAMINATION OF THE PERCEIVED IMPORTANCE OF TECHNICAL COMPETENCE IN ACQUISITION PROJECT MANAGEMENT

THESIS

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THESIS

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of the Air Force Institute of Technology
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Charles R. Baumgardner, B.S.
Captain, USAF

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Abstract

This research examined the importance Air Force acquisition project managers attribute to technical competence, and several individual and situational factors which might affect their perceptions of the importance of technical competence: extent of acquisition experience, degree of technical academic training, level of project technology, caliber of technical project team, and acquisition phase. A review of the literature revealed that previous studies of project and program managers suffered from several limitations with regard to a direct examination of the importance of technical competence. No single study has empirically supported a clear determination on the importance of this attribute to project managers. Considering the nature of today's projects and the ongoing dramatic rate of technological advancement and change, an investigation of the potential importance of technical competence in managing projects seems particularly critical for prospective project managers and those with little experience. In an empirical study of 228 acquisition managers, the findings show a majority consider technical competence as extremely important or absolutely essential, even though they may rank the attribute low in terms of use when compared to other skills. Further, the results indicate the importance of technical competence among acquisition project managers varies significantly as a function of technical project team capabilities and phase of the acquisition life cycle. In addition, the research suggests technical competence is an important contributor to project managers' ability to communicate.

AN EXAMINATION OF THE PERCEIVED IMPORTANCE OF TECHNICAL COMPETENCE IN ACQUISITION PROJECT MANAGEMENT

I. Introduction

> It really makes little difference whether our systems are large or small, complexity and human inputs characterize all our modern systems.... As problems become more complex and less amenable to solutions by quantitative techniques, people with the ability to handle such problems have become more scarce. Since the effective project manager can handle complexity and non-quantifiable parameters, the most important problem is that of obtaining more and better people for the job. Industry and government do not always recognize this problem, and often assume that any good manager can be effective as a project manager. Nothing could be further from the truth. Those organizations that recognize that they have a problem will readily affirm that they can find very few people with the ability to handle a large, complex, multi-disciplinary project. Deciding that we need more and better project managers is only the first step--then we are faced with the necessity of deciding exactly what type of person we are looking for. What specific skills and attributes are most valuable to the project manager? There is considerable disagreement as to which of the many skills are most important. (Stuckenbruck, 1976: 41)

Review of the general record of studies on the skills, traits, attributes and competencies of effective project managers makes this apparent. Although many studies have been conducted over the years (Barnard, 1938; Drucker, 1954; McGregor, 1960; Levinson, 1980) with several focused towards determining the characteristics of competent managers (Argyris, 1962; Bass, Burger, Doktor, & Barrett, 1979; Bray, Campbell, & Grant, 1974; Blake & Mouton, 1964; Hicks & Stone, 1962; Katz, 1955; Kotter, 1982; Stogdill, 1974)

as well as project managers (Cullen, Gadeken, & Huvelle, 1990; Gaddis, 1959; Gadeken, 1989b; Posner, 1987; Rubin & Seelig, 1967; Smythe & McMullan, 1975; Stuckenbruck, 1976a; Thamhain & Wilemon, 1978), disagreement continues regarding the importance of various skills required for effective performance. The variety of assumptions and research methodologies among studies may be part of the problem. Nonetheless, no singly robust and definitive assessment of overall project management competencies has been accomplished. Perhaps such a goal is idealistic and even unrealistic. However, the nature of today's projects makes it particularly critical for project managers, especially prospective project managers and those with little experience to realize the importance of the different skills and competencies which can contribute to their success. Certainly many conceivably important skills exist. Among the many, however, technical competence, or technical skill, technical expertise, and technical know-how by other names is one which deserves renewed attention.

Several related factors support the need today for acknowledging the potential importance of technical competence in managing projects both within industry and government:

- a dramatic rate of technological advancement and change (Cohen, 1986; Cook, 1971; Hoffman, 1989; Honens & Gould, 1988; Randolph & Posner, 1988; Thornberry & Weintraub, 1983)
- the expanded role of technology and technology management as principal factors in maintaining a competitive edge (Badawy, 1982; Boyatzis, 1982; Cleland, 1991; Hood, 1990; Sarchet, 1969; Thornberry & Weintraub, 1983)

- a greater emphasis on research and development (Badawy, 1982)
- the growth in technical scope and complexity of projects (Fox, 1990; Honens & Gould, 1988; Stuckenbruck, 1976; Thamhain, 1984)
- an apparent increased demand for technically competent project managers (Cohen, 1986; Cook, 1971; Fox, 1990; Hoffman, 1989; Hood, 1990; Randolph & Posner, 1988; Rosenbaum, 1990a; Soffron, 1986; Thamhain, 1989)

Background

Within the realm of private industry, some authors (Sarchet, 1969; Boyatzis, 1982) describe technology and managerial skills as the prime factors in raising *per capita* production in the United States and putting American business ahead of many competitors in the international market. This kindred relationship to business productivity and success is almost sure to continue, but the benefits of ongoing technological growth may not be realized without corresponding improvements in managing the growth. With the enduring and rapid expansion of technology in levels of complexity and innovation (Cohen, 1986; Hoffman, 1989; Office of Technology Assessment, 1984), managerial skills and effective management of technology and technological innovation will also become more critical (Cleland, 1991; Cleland & King, 1983; Thornberry & Weintraub, 1983). Various researchers, in fact, cite technology as dictating not only the need for more effective project management (Randolph & Posner, 1988), but also the need for more technically competent managers to successfully handle the increase in technological complexities (Cohen, 1986; Hoffman, 1989; Kozlowski & Hults, 1987; Soffron, 1986; Thornberry &

Weintraub, 1983). In scope, the relative impact is broad. The rate of technological change has taken on significance not only in industry, but in the context of the Department of Defense (DoD) acquiring and developing weapon systems as well.

Resource constraints and the growth and increased complexity of technologies encompassed by many DoD projects have drawn attention to the managerial abilities of those selected for the acquisition workforce. "In an age when technology is increasing at a geometric rate, and resource dollars are becoming more and more scarce, the selection of program managers to meet the challenge of resource management is of crucial importance" (Cook, 1971: 34). The importance lies partly with the nature of acquisition manager jobs. DoD program managers are primarily involved in planning, contracting, monitoring, controlling, and evaluating the technical performance of contractors and government agencies (Fox, 1990:12). The complexities of managing the development and production of multi-billion dollar weapon systems require these skills to be highly developed (Fox, 1990: 12).

Considering some experts' (Fox, 1990; Wade 1986) belief that improving the DoD acquisition process is dependent on improving the acquisition workforce and recognizing the technical responsibilities of the workforce appear to be increasing, technical competency among DoD acquisition managers warrants attention. Research (Pinto & Slevin, 1989a) has indicated the success or failure of projects is subject to strong influence by a project manager's competence, technically and in other areas. Further, technology makes facets of the project manager's job different

(Stuckenbruck, 1986), as Martin (1986) illustrates in describing the Project Management Body of Knowledge (PMBOK) continuum (Figure 1).

Martin (1986) depicts the PMBOK as the center of a know-how continuum, the link between on-going management at one end and technical management on the other.

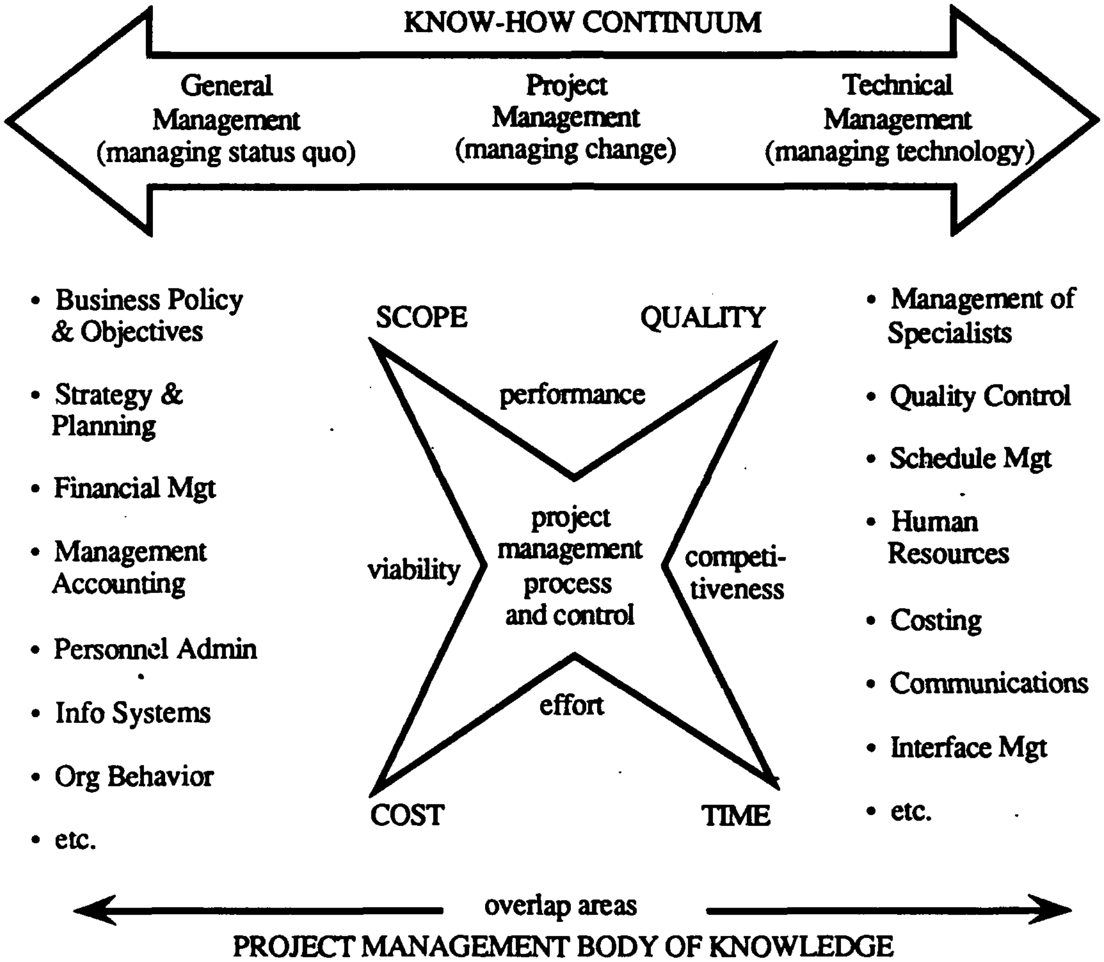


Figure 1. Project Management Body of Knowledge (Source: Martin,1986: 19)

A "process/control" overlay dominates the center of the model and combined with the basic program manager functions signifies project integration (Martin, 1986). The project manager functions which are more

subject to influence by particular technologies are grouped under *Technical Management* within the continuum. As Martin states, "This gives rise to the "Areas of Overlap" between generic PM and field specific PM as shown on the right-hand side of the PMBOK diagram" (1986: 18), which bear some significance. According to Martin:

> The overlap areas infer that PM staff must have sufficient understanding of the various specialist disciplines to appreciate project requirements and issues. They must be able to communicate appropriate direction and means of conflict resolution to these specialists in order to reach a successful project conclusion. (1986: 19)

Subsequently, in view of the now spectacular rate of technological change (Cohen, 1986; Hoffman, 1989; Randolph & Posner, 1988; Thornberry & Weintraub, 1983), the question might be raised whether such change has effected an increase in the importance of having technical competence, an understanding of specialist disciplines (Katz, 1974) with the ability and capacity to use technical information in managing projects (Kerzner, 1984). Unfortunately, making any assessment of the importance of technical competence for project management from past studies in industry or DoD is difficult.

Limitations of Past Studies

Previous studies on managers and project managers present several limitations with regard to an examination of the importance of technical competency. Difficulties with earlier research stem from three particular areas:

- limited focus... characterizing and assessing the importance of technical competence primarily in terms of technical academic training

- lack of distinguishing between organizational needs and personal motivations...technical competence among project managers often exists as a result of career choice among engineers, not necessarily a need for technical know-how in project management

- low variance in the backgrounds of research participants...the majority of studies have been conducted among engineering managers, and as a result accurate measure of the importance of technical competence frequently appears obfuscated by engineer-managers' needs for interpersonal skills which they often lack (Beall & Bordin, 1964; Bennett & McMullen, 1987; Brown, 1976; Sarchet, 1969).

The following sections elaborate on each of these areas.

Technical Education and Technical Competence. First, several studies focus consideration on educational backgrounds (Chambers, Henderson, Jones & Solomon, 1970; Dwyer, 1990; Miller, 1987) and primarily relate technical competency to the engineering schooling common among many project managers.

For example, based on data collected through interviews with DoD acquisition program managers and their technical advisors, Miller (1987) found managers with electrical, computer, or aeronautical engineering degrees were perceived (by themselves, as well as by their advisors) as significantly higher in technical competence than managers having business and/or management degrees. Miller (1987) subsequently concluded that the perceived technical competence of program managers differed based on educational background. The results did not, however, indicate technical degrees resulted in technical competence (Miller, 1987). Demographically, other evaluations of DoD acquisition project managers

(Chambers *et al.*, 1970; Dwyer, 1990) have shown a disproportionate share of managers who have successfully progressed to top leadership positions do possess engineering degrees.

A system analysis of DoD acquisition program directors conducted in 1970 revealed over ninety-nine percent had technical undergraduate backgrounds (Chambers *et al.*, 1970: 19). More recently, Dwyer found "over seventy-one percent of a sample of sixty [program] directors..." in Air Force Systems Command (AFSC) had technical degrees (1990: 33). Further, Air Force officials responsible for selecting and assigning acquisition officers report "a historical emphasis on recruiting personnel with technical backgrounds for the acquisition career field continues" (Sanford, 1991). While not empirically supported, the belief is that prospective acquisition managers with technical academic backgrounds are generally more technically competent and will consequently have a better ability to effectively manage acquisition projects (Sanford, 1991).

Career Path and Technical Competence. The next somewhat related dilemma in assessing the importance of technical competence is highlighted among other studies. Some research (Badawy, 1982; Brown, 1976; Smith, 1969; Soffron, 1986) cite demographics pointing out the increased numbers of engineers transitioning to management. As many of these studies reveal, the move to management roles by technical specialists may not be so much a response to organizational needs for technically competent managers, but merely the result of engineers desiring management positions.

As Crane explains, "Most engineers think sooner or later of switching from technical work to a managerial position" (1969: 5). Recognizing

engineers or technical specialists may simply choose and/or be selected for a management job muddles the capacity to determine whether the technical abilities they may bring with them are actually needed. Further complicating the problem is the evident trend in more and more individuals with technical/engineering degrees filling management positions (Smith, 1969; Brown, 1976; Soffron, 1986).

In 1955, Given (1955) wrote, "... the number of engineers in management has increased amazingly." As an example, Given (1955) revealed that over half the top 25 management positions in the company he was employed by were filled by engineers. In 1963, Hower and Orth observed, "... technically trained people have been working their way into the managerial hierarchy to an extent undreamed of only two decades ago" (1963: 301). Six years later Sarchet predicted "... by 1980 more than 50% (of corporations) will be headed by men with an engineering background" (1969: 944). During the same year, Smith stated, "Studies indicate that about 50% of the top executives of the *largest* American industrial concerns have scientific and engineering backgrounds and that this percentage is expected to increase" (1969: 949). As data from a 1969 National Engineers Registry Survey (Figure 2) reveals, the involvement of engineers across several levels of management even at that particular time was relatively significant. More recently, a 1988 report by the National Science Foundation (NSF) provided estimates showing even further increases in the participation of engineers and scientists in management. The NSF research indicated that while the total number of technical professionals would nearly double between 1980 and 1988, the number of engineers and

scientists in management positions would increase almost 130 percent (Crowley, 1982; Lane, 1988).

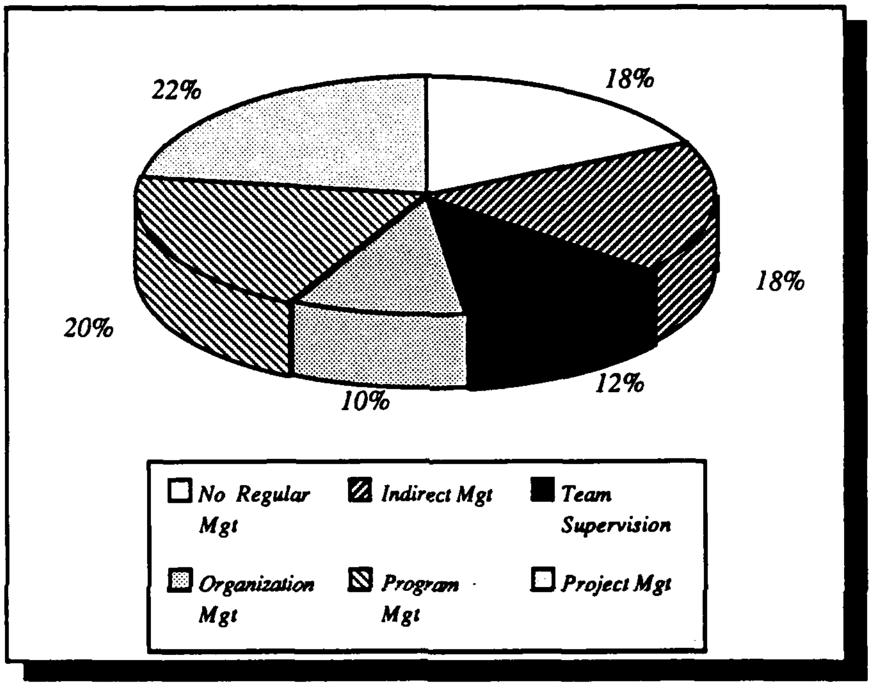


Figure 2. Supervisory Responsibilities of Engineers
(Source: Amos & Sarchet, 1981, citing Engineering Manpower Bulletin #25, Engineers Joint Council, Sept. 1973)

The overall trend for engineers becoming more involved in management is evident. The question is does the trend correspond in any measure to a parallel growth in technology and perhaps a related need for more technically competent managers.

Engineers' Needs for Other Skills. The study environments of a majority of project manager research reflect the remaining difficulty with determining the importance of technical competence. Many investigations of the importance of various project manager competencies and skills (Posner, 1986; Posner, 1987; Thamhain, 1989; Thornberry, 1987; Thornberry

& Weintraub, 1983) have been conducted primarily with the participation of high-technology organizations and engineering managers. In such studies, technical competence among engineer-project managers appeared to be considered a given fact, either by virtue of experience or education. As a result, the individual importance of technical competence was often overshadowed by skills more relative and significant to the particular ability of engineers to perform effectively.

In point of fact, many of the studies (DiMarco, Goodson & Houser, 1989; Gadeken, 1986, 1989; Guteral, 1984; Thornberry, 1987) tended to highlight the significance of project managers' interpersonal skills. A multiyear research program conducted by the Defense Systems Management College (DSMC) (Gadeken, 1989) serves as an example. Even though suggesting effective project managers in defense acquisition possess several competencies, the majority of the competencies noted for importance were related to interpersonal (human relations) skills, like interpersonal assessment, relationship development, and political awareness (Gadeken, 1989: 23). Undoubtedly, interpersonal competence is of some importance. What is not so clear is whether seemingly assumed technically competent individuals are actually required to effectively manage projects, particularly technically-oriented projects. How important is technical competence in these environments? Does the level of importance vary?

Air Force Acquisition Managers and Technical Competence

Current legislation and Air Force regulations do not reveal a clear position on the importance of technical competence either. Consider

briefly, the present education and training requirements for DoD acquisition managers.

For the most senior Air Force acquisition managers, United States Code Title 10, Section 1622 requires "that before being assigned to duty as a program manager, a person (1) must have completed the program management course at the Defense Systems Management College...; and (2) must have at least eight years of experience in the acquisition of weapons systems..." (U. S. Congress, 1991: 138). In addition, the code states, "A period of time spent pursuing a program of postgraduate education in a technical or management field... may be counted toward the eight-year requirement..." (U. S. Congress, 1991: 139). No priority is given to either management or technical academic training.

Air Force Regulation 36-27, Acquisition Professional Development, is equally vague with regard to preferences in the educational backgrounds required of acquisition managers at other levels. Lieutenants and captains may have either a bachelor's degree in engineering, business administration, or management; and lieutenant colonels or colonels may have a master's degree in any one of the three same areas as well (Department of Defense, 1990).

Retrospect

In view of the information presented up to this point, a direct examination of the importance of technical competence to project managers seems warranted for several reasons:

- rapid technological change may require more technically competent project managers

- past studies have not appeared to support adequate investigation of the importance of technical competence due to limitations in focus, inadequate distinction of forces motivating increased numbers of engineers in project management, and overemphasis on addressing skill requirements of managers assumed already technically competent

- current government and Air Force requirements may not satisfactorily support education and training of an acquisition corps capable of managing the technical challenges of future projects.

Technological change may very well require greater levels of technical competence among project managers. Unfortunately, studies on the importance of project manager skills have not made the determination clear. First, an individual's academic background does not guarantee nor necessarily comprise the full measure of what may be defined as technical competency (Miller, 1987). Technical competency arises from many factors (Katz, 1974; Kerzner, 1984; Miller, 1987). Furthermore, the fact a particular project manager has an engineering background does not necessarily mean it is needed. As noted by several authors (Albright & Glennon, 1961; Amos & Sarchet, 1981; Miles & Vail, 1960; Meisel, 1977; U.S. Dept. of Labor Statistics, 1990), many scientists and engineers transition to management whether or not actually demanded as managers. Many technical specialists make the move because they view the managerial path as the route to success (Argyris, 1957; Given, 1955) and/or find it more profitable in terms of salary (Alden, 1975; Brown, Grant & Patton, 1981). In fact, some even anticipate promotion to management as the reward for more effective performance (Thompson, Bowden & Price, 1975). These arguments apply

not only to industry, but equally well in some aspects to the defense acquisition workforce.

In particular, the reason the Air Force acquisition workforce is characterized by a significant number of individuals possessing technical backgrounds is partly the result of manning adjustments--not because of a direct requirement for technically competent managers. For instance, in early 1985 HQ AFSC sponsored a redistribution of engineers from overmanned positions to the program management career field "to strengthen the engineer mix," while simultaneously moving a commensurate number of nonengineer program managers to undermanned support officer careers (Skantze, 1985). The same *modus operandi* apparently continues today, at least in selection of military officers for the acquisition corps. Assignment officers at the Air Force Manpower and Personnel Center report an emphasis is still placed on recruiting as many engineers as possible for acquisition management (Sanford, 1991) ... yet, without concrete justification. In general, no studies have shown that project managers, particularly acquisition managers in DoD without technical backgrounds are not performing with equal effectiveness.

Specific Problem

Clearly, uncertainty exists regarding whether technical competence is an important attribute for project managers. Is technical competence important to project managers? Specifically, is technical competence becoming more critical to the ability of DoD acquisition project managers to effectively manage projects today? What factors if any influence the importance of technical competence in acquisition management? The

growing complexity of technology and Air Force acquisition programs in turn, appears to require an answer to these questions.

Past studies have not distinctly answered the question of the importance of technical competence, and certainly have not directly investigated how the importance varies as a function of individual and situational factors. As a result, this research will specifically examine the importance of technical competence to DoD acquisition project managers and how various factors, extent of acquisition experience, level of project technology, degree of technical academic training, caliber of technical project team, and acquisition phase may influence the importance of technical competence among acquisition managers. Further, in support of improving current education and training (assuming such a requirement exists), the study will also focus on investigating how acquisition managers perceive various methods contribute to acquiring and developing technical competency.

Research Questions

This research addresses the following questions in examining the importance of technical competence in acquisition management:

1. What is the perceived importance of technical competence to acquisition managers?

2. How does the perceived importance of technical competence vary as a function of personal or situational factors?

3. Does the perceived importance of technical competence relative to other competencies vary as a function of personal or situational factors?

Hypotheses

This study involved examination of 19 hypotheses. These are presented in the methodology, Chapter 3, as part of the discussion of the survey instrument.

Summary

This study will pursue an effort to reduce the void in project management studies relative to direct examination of the importance of technical competence. Although much has been written on skills and abilities required to be an effective project manager, there are very few direct assessments of the perceptions of project managers on the importance of technical competence as an individual attribute. Undertaking an effort to obtain and analyze the perceptions of DoD acquisition managers on the importance of technical competence will provide more insight on the significance of this attribute and the overall balance of skills needed in acquisition management.

The study will not only explore the importance of technical competence to acquisition project managers, but also factors which may need to be considered when assessing the requirements for technically competent managers. A literature search and survey will serve as the primary tools in accomplishing these objectives.

The initial part of the research will focus on developing a comparative basis for examining the importance of technical competence in project management by providing a review of literature on the progression, results, and problems characterizing leadership and general management studies. Similarities exist between project management and general

management studies in several areas, from methodologies to ambiguity of results. Recognizing some of the similarities, especially relative to the attributes revealed important in general management will provide an appreciation for why certain skills are also reported significant to project managers. At the same time, a brief examination of general management studies should also allow a more complete understanding of the uniqueness of project management, especially as possibly associated with technology and perhaps the importance of technical competence.

After highlighting the evolution of project management, a portion of the literature review will subsequently address issues relevant to engineers, generally assumed a technically competent group of individuals, and their history in project management roles. Here the study focuses on revealing both positive and negative aspects of technical specialists as managers.

The final part of the review will include a comprehensive examination of the body of project management studies performed to date, giving emphasis to extracting information pertaining to technical competence. Factors revealed in the literature which appear to influence the importance of technical competence will provide the basis for developing a data collection instrument supporting the overall study.

In the chapters following the literature review, the methodology used to acquire data for the study is presented, and the results of data analyses are reported with applicable recommendations. Specifically, the methodology chapter describes the study population, the sample taken, development of the data collection instrument, and the analytical tests used in data analyses for the study. The results chapter presents the analyses

addressing the 17 hypotheses proposed for the study. Additionally, comments on survey topics provided by respondents are revealed. Finally, recommendations are made with regard to statistical results, comments by respondents, and in consideration of the literature reviewed for the study.

Definitions

Before proceeding, the following key terms are defined to support a better understanding of the scope and focus of this study. Special attention should be given to the definitions provided for technical competence and project/program manager to avoid potential confusion with conceptual use of these terms apart from this research. In particular, note this study makes no distinction between a manager working in projects, programs, or in any of the different positions held by acquisition managers in DoD. Making this generalization supports examination of technical competency in acquisition management as a whole.

1. project: an organization of people dedicated to a specific purpose or objective, generally involving large, expensive, or high-risk undertakings which have to be completed by a certain date, for a certain amount of money, within some expected level of performance (Tuman, 1983: 498).

2. program: used synonymously with "project" in the context of this research.

3. project management: comprises the planning, organizing, directing, monitoring, and controlling of organizational resources for a relatively short amount of time to complete desired goals and obtain more effective and efficient use of resources (Dressler, 1986; Badawy, 1982; Fox, 1990).

4. program management: equates to project management in the scope of this study, although generally, "programs are usually larger than projects" (Rosenau, 1981: 3).

5. project or program manager: used interchangeably in this study; within DoD, a professional acquisition management officer (military or civilian) who is employed in the defense acquisition field, and is familiar with the system acquisition process. Such individuals will generally be referred to as *acquisition managers*.

6. competency: an underlying characteristic, body of knowledge, motive, trait, self-image, social role, or skill of a person that is causally related to superior job performance and an individual's existing capacity to interact effectively with his environment (Hayes, 1979; Klemp, 1980; Wagner & Morse, 1975). Examples might include technical expertise, management and leadership skills (Gadeken, 1989).

7. technical competence: with respect to project/program management, the expertise composed of an understanding of the:

- Technology involved
- Engineering tools and techniques employed
- Product applications
- Technological trends and evolutions
- Relationship among supporting technologies (Kerzner, 1984: 170; Kerzner & Thamhain, 1983: 263 -272; Thamhain & Wilemon, 1978: 102).

In general, technical competence or skill "implies an understanding of, and proficiency in, a specific kind of activity... involves specialized knowledge, analytical ability within a specialty, and facility in the use of tools and techniques of the particular specialty (Katz, 1974: 91).

More specifically, the term *technical competence* in this study denotes the ability and capacity to understand and use technical information in managing projects or programs, particularly in regard to properly evaluating technical project issues, concepts, and solutions, and the consequences of related project /program actions or decisions.

8. technical performance: covers not only the engineering aspects of a weapon system but the contractor's management of resources (costs) and subcontractors. (Fox, 1990: 12)

9. skills: implies an ability which can be developed, not necessarily inborn, and which is manifested in performance, not merely in potential (Katz, 1974: 91)

10. human relations (interpersonal) skill: the capacity of a person to communicate his feelings and ideas to others, to receive such communication from others, and to respond to their feelings and ideas in such a manner as to promote better mutual understanding in specific situations and to foster individual behavior which more effectively takes into account the many facets, complexities, and personal interests involved in those situations (Hower & Orth, 1962: 39).

11. traits: categories for the orderly description of behavior; categories that are concerned with the organization and interrelationships of behavior, that refer to the organization and interrelationships of behavior, that refer to relatively enduring characteristics, and that differentiate an individual from others (Barge, Hough, Kemery, Dunnette, Kanfer, Kamp, & Cardozo, 1984: 3).

12. personality: the dynamic organization within the individual of those psychophysical systems that determine his unique adjustments to his environment (Allport, 1937: 48).

13. expert power: refers to the ability of a project manager to get the contributors to his project to do what he wants because they attribute greater knowledge to him or believe he is more qualified to evaluate the consequences of certain project actions or decisions (Archibald, 1976: 45).

14. manager: one who gets work done through other people (Couey, 1969: 8). Also referred to as an administrator (Katz, 1955) or executive within the scope of this study.

II. Literature Review

Introduction & Scope

A substantial body of studies ranging from general management to project management exists on the competencies and skills of managers. This chapter to an extent aims to glean information from across the entire spectrum. As a result of advancing technology and the challenges associated with managing increasingly complex technological tasks, project management has emerged as a unique managerial discipline. Yet, the competencies and skills most important to project managers for effective performance do not appear altogether different from those general managers value. Particularly unclear, is whether technology has indeed made technical competence to be perceived as an important attribute by project managers. At a time when technological innovation is progressively dominating manufacturing, the competitive stature of businesses, as well as development of viable weapon systems, this seems especially crucial to assess.

The intent of this review is to support an assessment which may potentially contribute to improvements within the DoD acquisition project management workforce. The review covers four main areas. Foremost, this chapter examines the variety of studies on project managers to investigate importance possibly attributed to technical competence, and any factors suggested to influence perceptions about the importance of technical competence. First, however, the review focuses on briefly highlighting the history of methodological problems among general studies of managers and leaders. Attempts at characterizing the effective and successful

manager and leader have reflected a variety of approaches and weaknesses. Ambiguities in identifying the skills important to effective managerial performance have continued over time and still pervade management studies across the variety of management disciplines, including project management. After the history, this chapter provides a concise review of studies on general managers to highlight similarities and differences in findings with studies of project managers. Following this section, the review briefly examines the development of project management from traditional management, and evolution of the technical project manager. Combined with the previous sections, this completes a comprehensive basis for examining the importance of technical competence among the various studies on project manager skills.

Management and Leadership Studies

Some argue whether management is actually synonymous with leadership (Plachy, 1981; Sarkesian, 1985; Zaleznik, 1979, 1989, 1990), but studies of managers and leaders reveal much in common. From focus to inconclusiveness of results, parallels exist in many respects among the range of theories and models which have been posited on management and leadership. Briefly acknowledging the similarities in part, underscores why ambiguities persist with regard to trying to identify and evaluate the attributes which characterize effective or successful managers and consequently project managers.

According to Cohen (1980), studies on leadership have been categorically focused on personal traits of leaders, leader behavior, leadership situations, or a combination of these. Similarly, studies of

managers have also concentrated on personal traits (Ghiselli, 1959; Hicks & Stone, 1962; Mintzberg, 1980), characteristics (Gaddis, 1959; Mahoney, Sorenson, Jerdee, & Nash, 1963; Rawls & Rawls, 1968), manager behavior (Manz, Adsit, Campbell, & Mathison-Hance, 1988; McClelland & Boyatzis, 1984; Soffron, 1986), management situations (Hower & Orth, 1963; Shannon, 1980; Wilemon & Cicero, 1970), or a mixed consideration of factors like occupation and personality (Beall & Bordin, 1964; Levine, 1963; Katz, 1974). While centering on many of the same approaches to characterize effective individuals, leadership and management studies have also shared some of the same limitations motivating changes in study focus.

With regard to leadership, some correlations have been found among certain traits and leadership, but not enough to explain leadership or management effectiveness in many situations (Cohen, 1980, 1986; Daft & Steers, 1986; Gadeken, 1986; Mintzberg, 1980). Efforts by researchers to define an equation and model of leadership in terms of leaders' and managers' behavior patterns followed in reply (Cohen, 1980, 1986; Daft & Steers, 1986). While the resultant behavioral models did offer some advances in explaining effective leadership, some theoretical inconsistencies remained (Cohen, 1980, 1986; Daft & Steers, 1986; Gadeken, 1986). Researchers responded by developing "contingency" models with consideration for both leadership style (of managers and leaders) and the leadership situation (Cohen, 1980, 1986; Daft & Steers, 1986; Fiedler, 1965; Mintzberg, 1980; Tannenbaum & Schmidt, 1973). Many of these models are still used today to select leaders and managers and to help them learn more about the leadership process (Cohen, 1980, 1986). Even so, studies on

leadership and management continue in efforts to better characterize the attributes and skills needed for effective performance.

Characterizing Effective Managers

Characterizing the ideal executive or manager has been a difficult task for several reasons. To begin with, it has been a complicated matter simply to define a "manager" or "executive." Managers, executives and administrators in the corporate world, constitute a very heterogeneous group of people with a wide variety of job functions, often different even when addressed under the same job titles between companies (Brown, 1976: 87). Strong acknowledged this issue in a study several years ago.

> Everyone takes it for granted that he has a clear concept of an executive. If pressed for a definition he makes an attempt, then becomes confused, and finally resorts to giving examples. If all agreed as to who are executives in a given community there would be a basis for analyzing out the common elements in the men named, or their jobs. But those whom the writer has asked have not agreed. All consider that the men who are actually at the head of very large corporations are executives; they believe also that men who are vice-presidents or superintendents of production in large plants are executives. But there is no unanimity when the heads of finance, engineering, sales, or personnel departments are mentioned, nor agreement with respect to the heads of banks, brokerage houses, retail stores, etc. (Strong, 1927: 345)

Almost 30 years later, Katz wrote, "Although the selection and training of good administrators is widely recognized as one of American industry's most pressing problems, there is surprisingly little agreement among executives or educators on what makes a good administrator" (1955: 33). Indeed, limited progress appears to have been made in identifying the ideal executive. Without specific agreement on who or what managers are, results of studies have differed in many instances with conclusions limited

to the generic when applied to the broad body of management. Still other issues have also served to complicate generalization of findings across manager studies.

For one, managers and managerial jobs have often been incorrectly assumed as "fixed or static entities" (Campbell, Dunnette, Lawler & Weick, 1970:13). While this premise has made personnel selection and job placement a much simpler matter, it has been unrealistic overall (Campbell *et al.*, 1970). Many studies have been conducted to define the qualities needed by executives, and it has been easy to show a large variance in the qualities possessed by successful managers within any given company (Stryker, 1954). Moreover, it is the inadequacy of the qualities (trait) approach standing alone that motivated establishment of managerial training programs in firms.

Managerial training and development programs were created for the purpose of changing "managers' knowledge, skills, and other behavioral tendencies in order to equip them to more successfully meet the demands of their jobs; thus, training and development assume modifiability in human traits..." (Campbell *et al.*, 1970: 13). However, too narrow a focus on training and development of managers has not been an optimal method to assuring effective managerial performance either.

As some studies have shown (Katz, 1955; Katz, 1974), the approach has been taken to describe good executives not in terms of personality traits (qualities), but in terms of fundamental skills contributing to successful performance. Unfortunately, results of these studies are generally bounded, considering people are not perfectly trainable. If people were "perfectly modifiable through training," no need would exist for assessing

"individual abilities and motive patterns at the time of selection" (Campbell *et al.*, 1970: 13). On the other hand, if training and development made relatively little difference in individuals' performance, the need to assess individual characteristics would be very significant (Campbell *et al.*, 1970).

Notwithstanding, many organizations have assumed one of the two extremes in approaching how to identify and produce effective managers (Campbell *et al.*, 1970; Jennings, 1959). Some research has actually shown that certain industries reflect a distinct preference for either the theory managers are born and not made, or the reverse (Jennings, 1959), when in fact, neither is true in the extreme (Campbell *et al.*, 1970). As Lee (1988) points out, a balance of the approaches appears to offer the most towards developing the effective manager. Interestingly enough, this dichotomy of approaches has generally characterized many of the studies conducted on managers and contributed to the variance in conclusions on how to define the ideal or effective manager.

Managerial Traits

Numerous studies have been done concerning the traits of effective managers, with particular regard for distinguishing between less and more successful (effective) managers (Ghiselli, 1959; Hicks & Stone, 1962; Mahoney *et al.*, 1963; Rawls & Rawls, 1968). In fact, some personality trait investigations have revealed that not only can managers as a group (e.g., top managers) have similar managerial traits, but it is possible to differentiate less effective managers from more effective managers based on traits (Brown, 1976; Ghiselli, 1959; Mahoney *et al.*, 1963; Rawls & Rawls, 1968).

In a study involving a stratified sample of more than 800 managers, Ghiselli found that on five trait scales, consisting of intelligence, supervisory ability, initiative, self-assurance, and occupational level, more successful managers could be differentiated from less successful managers (1959). Porter (1961) conducted a similar study of 140 managers among 3 different companies, focusing on the perceived importance of 13 personality traits to success in management jobs.

Somewhat unlike Ghiselli's findings, Porter (1961) concluded mangers at different levels (middle management and below) tended to rank traits (the 13 represented in the study) similarly in relative perceived importance. Of the 13 traits Porter studied, *Cooperative* and *Intelligent* ranked the highest individually, but overall the traits relating to cooperativeness and willingness to adjust to others (conforming, cooperative, flexible, and sociable) ranked much higher in perceived importance on average than traits portraying individuality (aggressive, dominant, independent, original) (1961: 233). However, Porter (1961) also noted that when the respondents were grouped by management levels within companies, versus management level alone, trait rankings varied somewhat--apparently as a reflection of individual differences in organizational conditions.

As a follow-on to the Porter effort, Hicks and Stone (1962) carried out a study of 76 managers to determine in part if the traits Porter (1961) identified as important could be identified across a sample covering several levels of managers. Hicks and Stone (1962) found managerial success could be predicted to a significant extent, despite differences in areas of specialization (at least in the organization studied). Also noteworthy, the trait *Intelligent* was not found to relate significantly to managerial success

as in the Porter (1961) study (Hicks & Stone, 1962). This was explained as "the result of sample attenuation through preselection on education and career achievement," although it was also thought possible managers might have used other traits to describe intelligence or had simply assumed other managers in similar circumstances were intelligent (Hicks & Stone, 1962: 431). Lack of variance may also have contributed.

A study of 468 managers among 13 companies representing 5 different industries (Mahoney *et al.*, 1963) revealed results both analogous and yet dissimilar to the findings evidenced in research by Ghiselli (1959), Porter (1961), and Hicks and Stone (1962). Mahoney, Sorenson, Jerdee, and Nash (1963) concluded personal characteristics can differentiate more effective managers from less effective managers, even without regard for job assignment or type of company. Further, from among 5 dimensions of personal characteristics used in the study (intelligence, empathic ability, interests, personality, and personal history), the more effective managers on average were primarily found to be more *intelligent* and more *dominant* than less effective managers (Mahoney *et al.*, 1963).

In yet another study, Rawls and Rawls (1968) arrived at many of the same conclusions obtained in previous research. Using the Edwards Personal Preference Schedule and the California Psychological Inventory to form personality profiles of 30 successful and 30 less successful executives, Rawls and Rawls concluded:

> In general, the successful executive tended to be better informed and more efficient in his work; more self-reliant, independent, and imaginative; and more flexible and adaptable in his thinking... more responsive to the inner needs and motives of others... more persuasive, and consequently, to have greater leadership potential and initiative... more

> ambitious, competitive, dominant, aggressive, manipulative, and opportunistic in dealing with others. The less successful executive... was more likely to take suggestions from others and to accept the leadership of others... appeared to conform readily to custom, to do what was expected of him, and to be respectful and accepting of others. (1968: 1033 - 1034)

Although it is evident each of the studies cited have some commonality and potential in identifying effective managers, it should be equally clear that the trait descriptions of effective managers established are qualified. Generally, "Trait descriptions are loosely defined, and they do not pinpoint with sufficient precision the behavioral elements making up effective management" (Campbell *et al.*, 1970: 8). Mintzberg (1980) too suggests traits are intangible, difficult to directly relate to operations and the behavior of managers.

Understandably, these difficulties motivated researchers to alter the focus of managerial studies to skills, factors directly related to behavior and measurable, and subsequently to contingency management theories (Cohen, 1980; Mintzberg, 1980). Yet, as Mintzberg (1980) also proposes, the better theories of management and leadership should be founded on both an individual's basic characteristics, as well as those contingent on the situation.

According to Mintzberg, "the effective manager exhibits specific personal characteristics related to his particular job superimposed on the general characteristics that he shares with all effective managers" (1980: 194). As such, the intangible nature of assessing traits should not necessarily preclude investigation of personal characteristics (Mintzberg, 1980).

Altogether, the intent of reviewing these particular trait studies on managers has been to further accentuate some of the strengths and

weaknesses of the trait approach--many carry over to studies of project managers. Similarly, a very brief review of what may be considered a premier report on managerial skills follows to highlight a few elements which also often characterize studies of project managers.

Managerial Skills

In 1955, Katz suggested "effective administration rests on three basic developable skills which obviate the need for identifying specific traits and which may provide a useful way of looking at and understanding the administrative process" (1955: 34). The three skills of note are *technical, human,* and *conceptual* (Katz, 1955). *Technical skill*, as described by Katz (1955), implies special knowledge and analytical ability within a specialty; *human skill*, an individual's ability to work with people; and *conceptual skill*, the ability of the manager to see an organization and the forces acting upon it as a whole in decision-making.

Of technical skill, Katz observed:

> It is indispensable to efficient operation. Yet it has greatest importance at the lower levels of administration. As the administrator moves further and further from the actual physical operation, this need for technical skill becomes less important, provided he has skilled subordinates and can help them solve their own problems. At the top, technical skill may be almost nonexistent, and the executive may still be able to perform effectively if his human and conceptual skills are highly developed. (1955: 37)

At the same time, however, Katz (1955) provided the caveat that human and conceptual skills could compensate for a manager's lack of familiarity with the technical aspects of a job, particularly a new one.

Separately, human skill was considered important at all levels of administration (management), but most significant at lower levels where

the largest number of direct contacts with subordinates could occur (Katz, 1955). The importance of conceptual skill, on the other hand, was understood to increase and subordinate the importance of human skill as a manager moved farther up the organizational ladder and acquired more responsibility for policy and organizational actions (Katz, 1955).

With respect to developing the three skills, Katz (1955), citing research in psychology and physiology as support, suggested that whether individuals possess strong natural abilities or not, they could improve their performance and managerial effectiveness through training and practice. This belief ideally characterizes skill-insight theory... the idea managers are made and not born (Jennings, 1959).

Interestingly enough, in 1974 Katz refined some of the points he had made almost 20 years earlier. Specifically, Katz' (1974) original assessment of human skill was updated to reflect two separate requirements, one for internal intragroup skills in middle management roles or lower, and the need for intergroup skills which become progressively important as a manager moves up in an organization. In regard to conceptual skill, Katz (1974) suggested it may not actually be very developable, that is, it may be more accurately viewed as an innate ability considering the extent individuals learn to think in their early years. Last, in deference to technical skill, Katz (1974) made it the exception, rather than the rule, for technical skill to be unimportant at higher levels of management. In general, Katz (1974) asserted lack of technical skill may be compensated for by a competent technical project team, but the manager should recognize smaller organizations are often much less capable than large firms of supporting and fielding such a team. Overall, Katz (1974) admitted to an

over-simplified view of the manager's role, concluded with the proposition managers require some competence in all three skills, and the thought of managers being able to adapt their management styles and skills to best accommodate changes in the organizational environment.

In overview, Katz (1955, 1974) emphasized the importance of three skills, technical, human, and conceptual. It is interesting to note these same skills will be featured to some extent in studies of project managers. However, before reviewing the body of studies on project managers it is first necessary to establish the uniqueness of project management compared to management in general, and contrast technical managers with managers in general. Despite commonalities which may prevail between managers and project managers on the whole, differences distinguishing project management often motivate a somewhat different prescription for the manager of a project compared to that for the general manager within an organization.

> Managing projects is, without question, a different job. Not only does it require sophisticated tools and special organizational design considerations, but also a different breed of manager. (Thamhain & Wilemon, 1976)

Uniqueness of Project Management

Since the commissioning and completion of Oppenheimer's Manhattan Project, advancing technology has promoted fundamental changes in traditional management theory and practice (Gaddis, 1959; Soffron, 1986; Stickney & Johnston, 1978). During the 1950's traditional management approaches proved inadequate for management of complex technological tasks requiring integration of manpower and resources (Souder, 1979). "Classic management functions of control, communication,

and coordination" were deficient in unique endeavors characterized by uncertainty, finite duration, fixed budget, void of distinct organizational boundaries, and requiring a large proportion of highly skilled personnel working at various levels across a lifecycle of process phases (Gaddis, 1959: 90). Project management provided a framework for accommodating the combination of these factors (Archibald, 1976; Wilemon & Cicero, 1970).

In comparing project management and traditional, functional management, several distinctions appear. First, projects generally cut across organizational lines (Archibald, 1976; Gemmill & Thamhain, 1973; Posner, 1986; Thamhain & Wilemon, 1976, 1987), meaning the pyramidal hierarchy of personal relationships which describes the traditional organization (Soffron, 1986) does not dominate. Relationships exist in the project which are not directly constrained by a vertical chain of command, nor bound by functional separation, a distinct line/staff structure, or span of control (Wilemon & Cicero, 1970: 270).

Second, the standard superior/subordinate relationships which legitimize distribution of power, fix responsibility commensurate with authority, preserve unity of command and unanimity of objective in the traditional organization (Soffron, 1986), are commonly not represented in the project environment. To the contrary,

> Because many skills and disciplines located in organizations contribute to the project, the project manager rarely, if ever, has traditional authority commensurate with his responsibility. He must interact with several levels of the contributing organizations and give effective directions to persons not reporting to him. This disparity between responsibility and authority is a major point of departure from established management practices, and is a prime source of difficulty in achieving effective management of projects. (Archibald, 1976: 34)

Lack of formal authority (Gemmill & Wilemon, 1970) is certainly a problem, but it also relates to another plight of projects. Project managers are responsible for overseeing activities generally involving significant participation of manpower and organizations not under their control (Cleland & King, 1983; Gemmill & Thamhain, 1973; Thamhain & Wilemon, 1976). Lack of control, not being "the focal point for everything concerning the project and cognizant of all relevant activities" is one of the typical reasons for project management failures (Eveld, 1978: III-G.1).

Briefly, some of the characteristics distinguishing project management from functional management have been highlighted. These are summarized in Table 1. With a better understanding of the uniqueness of project management, hopefully it will be easier to view why studies have shown project managers require skills and abilities in addition to those needed for a traditional functional management job (Cleland & King, 1983; Gaddis, 1959; Soffron, 1986; Thornberry, 1987; Vanchieri, 1989; Wilemon & Cicero, 1970).

Engineers in Management

Several researchers and studies have acknowledged the growing number of managers who have engineering or scientific backgrounds (Brown, 1981; Sarchet, 1969; Smith, 1969; Saffron, 1986). Whether for reasons of improving advancement opportunities (Thompson, Bowden & Price, 1975; Thornberry, 1987; U. S. Department of Labor Statistics,1990), the potential for increased pay (Alden, 1975; Albright & Glennon, 1961; Amos & Sarchet, 1981), or the demand for technical expertise (Lock, 1969; Sarchet, 1969; Given, 1955) more and more engineers are indeed filling

management positions. However, in broad perspective, many authors suggest technological advances as the real basis for an engineer-to-project manager trend (Amos & Sarchet, 1981; Given, 1955; Hoffman, 1989; Sarchet, 1969).

TABLE 1

Comparison of Project and Functional Viewpoints

Phenomena	Project Viewpoint	Functional Viewpoint
Line-staff organizational dichotomy	Vestiges of the hierarchical model remain, but line functions are placed in a support position. A web of authority and responsibility relationships exists.	Line functions have direct responsibility for accomplishing the objectives; line commands, and staff advises.
Scalar Principle	Elements of the vertical chain exist, but prime emphasis is placed on horizontal and diagonal work flow. Important business is conducted as the legitimacy of the task requires.	The chain of authority relationships is from superior to subordinate throughout the organization. Central, crucial, and important business is conducted up and down the hierarchy.
Superior-subordinate relationship	Peer-to-peer, manager-to-technical-expert, associate-to-associate, etc., relationships are used to conduct much of the salient business.	This is the most important relationship; if kept healthy, success will follow. All important business is conducted through a pyramiding structure of superiors & subordinates.
Organizational objectives	Management of a project becomes a joint venture of many relatively independent organizations. Thus, the objective becomes multilateral.	Organizational objectives are sought by the parent unit (an assembly of suborganizations) working within its environment. The objective is unilateral.
Unity of direction	The project manager manages across functional and organizational lines to accomplish a common interorganizational objective.	The general manager acts as the one head for a group of activities having the same plan.
Parity of authority & responsibility	Considerable opportunity exists for the project manager's responsibility to exceed authority. Support people are often responsible to other managers (functional) for pay, performance reports, promotions, etc.	Consistent with functional management; the integrity of the superior-subordinate relationship is maintained through functional authority and advisory staff services.
Time duration	The project (and hence the organization) is finite in duration.	Tends to perpetuate itself to provide continuing facilitative support

Source: Cleland & King, 1983: 229. Systems analysis and project management.

Yet, although technology has seemingly influenced the demand for engineers as project managers, the fact more engineers are serving as managers and project managers has also resulted in several concerns. After highlighting some of the positive aspects of engineers as managers, the more significant concerns will also be summarized.

Positive Aspects of Engineers as Managers

According to Badawy (1982), engineers seem to have some qualifications befitting of management jobs. Engineers' general analytical skills, proficiency in optimizing complex systems, and use of quantitative and simulation techniques is integral to managerial problem solving and decision making (Badawy, 1982). Although a technically-oriented background is not the only requisite for managerial capability (Badawy, 1982; Popper, 1971), such training is valuable in taking on many management roles (Badawy, 1982; Crane, 1969; Given, 1955).

Crane (1969) describes engineering training as a priceless asset, advocating that such training commands respect from non-engineering management while placing the ex-engineer in the premier position as source for opinions and decisions on technical issues. In fact, Hoffman (1989), citing a report by Simon Ramo in *The Business of Science*, attributes the success of many large post-World War II businesses to the specialized training and technical education of engineers who organized and managed them:

> ... their specialized training allowed them to identify a broad range of goods and services essential to a healthy, growing economy. Moreover, their technical and scientific education was needed to solve design, engineering, and production

> problems to quickly and efficiently move products from the drawing board to the consumer. (Hoffman, 1989: 3)

Given (1955) too, observed engineering training and a technical background as assets to management responsibilities. In particular, Given emphasized the significance of engineers' "orderly processes of thinking" which frequently made the difference in solving sales problems (1955: 44).

In addition, Badawy (1970, 1982) suggests engineers and managers appear to have reasonably similar career objectives and cultural orientations. Moreover, engineers, like managers, generally have goals which are aligned with those of the organization (Badawy, 1970, 1982). Beall and Bordin (1964) offered this same proposition in a previous investigation of data collected on engineers.

> The production of goods and materials involves an organization of men and machines. The engineer must necessarily identify with that organization. That he is usually well suited to such a function is indicated by the regularity with which engineers rise to the top layers of these organizations. (Beall & Bordin, 1964: 26)

Engineers and Difficulties in Management

As engineers are assuming management roles and filling the need for managers capable of handling technology's increasing importance and complexity, they are also apparently bringing with them several challenges. In particular, Badawy (1982) has observed the nature of engineers as a group, their technical education, and organizational management among the factors which tend to make the transition difficult (Table 2). Indeed, several authors attest to many of the same issues which Badawy (1982) endorses as making the engineer's move and service in the managerial role troublesome.

TABLE 2

Causes of the Troublesome Transition from Technologist to Manager

1. The nature of technical education
2. The nature of the organization's management systems and policies a. Technical competence as a criterion for promotion b. The dual-ladder system c. The nature of the management task
3. The nature of scientists and engineers as a group a. Bias toward objective measurement b. Paralysis by analysis c. Fear of loss of intimate contact with their fields d. Technologists as introverts e. Poor delegators f. Inadequate interpersonal skills

Source: Badawy, M. K. 1982: 43. Developing managerial skills in engineers and scientists.

For one, the differences between managerial and engineering work as a whole tends to present a significant dilemma for engineers (Amos & Sarchet, 1981; Badawy, 1978, 1982; Crane, 1969; Shannon, 1980). As Crane explains,

> In engineering, you work with specifics-weight, length, height, pressure, force. In management you work with generalities-supervision, arbitration, sales delegation, negotiation. Engineering has its neat slide rule, graph paper, handbooks, laboratory test- and formulas... Management, too, has its tools. But they are crude compared to the precise tools of engineering... because the problems of management are affected by so many variables, human, economic, and political. So the first difference you'll find between engineering and management is one of specifics versus generalities. In engineering there is almost always an equation you can use or develop. In management there is hardly ever an equation to apply. (1969: 5)

In other words, in management the engineer can no longer rely on finding one "right" answer to problems. The management world is not "neatly bounded by slide rules, formulas, and handbooks," but instead is constantly changing (Crane, 1969: 5). In management, "There's only a workable answer that may be right today and wrong tomorrow" (Crane, 1969: 5). The engineer as a manager must then learn to accept a different mindset about problem-solving in response to changes in external conditions which can characterize the management environment (Crane, 1969). Given (1955), citing a Westinghouse executive described the issue this way:

> Many engineers do not believe in the importance of things which cannot be measured-such things as attitudes, emotions, customers, traditions, prejudices. As a consequence they fail to deal with those things which cannot be solved by logic alone. Yet the nonlogical (not illogical) is the crux of most business. (1955: 44)

A second area of concern is directly related, the involvement of people. Designing new machines and writing specifications does not require the same level of involvement with people as delegating work, resolving conflicts, and making decisions on projects whose outcome is uncertain (Crane, 1969). The qualities which may earn an engineer a management position generally require an ability to work alone, not with people (Amos & Sarchet, 1981; Crane, 1969). In contrast, management, by definition subsumes involvement with people and some competence in human relations (Crane, 1969; McCarthy, 1978; Daft & Steers, 1986). In fact, Brown (1976) using a California Psychological Inventory to compare 71 individuals (categorized as either managers, manager-engineers, or engineers) concluded "There appears to be a general quality of preferring to direct and interact with others which marks managers" (1976: 133). The essence of

this issue, managers' and perhaps engineer-managers' ability to handle people, is emphasized somewhat by Glaze (1989):

> ... management behavior, or *competence* to give the name by which it has become known, has become a prominent issue. Specialist or professional expertise still may be an important requirement in many jobs, but behavioral factors are increasingly at the heart of management excellence. As the song has it, "It ain't what you do, it's the way you do it, that's what gets results." This demonstrably is true, even in technical departments.... (1989: 72)

Many studies on engineers (Beall & Bordin, 1964; Bennett & McMullen, 1987; Brown *et al.*, 1981; Given, 1955; Sarchet, 1969) have suggested engineers lack the level of capability to interact with people that is generally associated with managers. Moreover, those engineers who fail as managers often do so because they are not sensitive to people-related concerns (Munson & Posner, 1979). In fact, many studies (Beall & Bordin, 1964; Bennett & McMullen, 1987; Brown *et al.*, 1981; Goshen, 1969) propose engineers possess certain personality traits or may not have others (Hoffman, 1989) which appear to make them unbefitting of managerial positions. Brown, Grant and Patton (1971) cite several researchers, Roe (1950, 1951, 1953, 1957), Holland (1959, 1962), Super (1953), and Super, Starishevsky, Matlin, and Jordaan (1963) offering this opinion. As Brown (1976) suggests, in describing research by Steiner (1953), Goshen (1969), Gray (1963), Freyd (1924), Izard (1960) and Landes (1972), engineers seem to have personalities oriented to dealing with things rather than people. This relates to yet another dilemma for engineers moving to management roles.

Researchers (Crane, 1969; Given, 1955) have pointed out engineers must often learn to think and make decisions faster once in management. The laborious decision-making processes which previously accommodated

analysis of facts are not appropriate in dealing with people and environments of uncertainty (Badawy, 1982; Crane, 1969; Given, 1955). In management, "you seldom have time to spend days and days analyzing a situation," (Crane, 1969: 6) and often it is more valuable to have an answer on time, though not absolutely correct, than to have the right answer weeks later (Given, 1955).

Additionally, engineers have been observed as having a tendency to remain fixated on their old function, reluctant to delegate, lacking trust in others' abilities, and choosing to be personally involved in subordinates' engineering work often to the detriment of their ability to serve effectively as managers (Amos & Sarchet, 1981; Badawy, 1982; Given 1955; McCarthy, 1978; Shannon, 1980). Hower & Orth (1963) described the effects of such actions in the following manner, based on a series of case studies involving 27 industrial laboratories and more than 70 managers in R&D companies:

> Administration [management] action is not likely to succeed unless based on good information and ideas. No one person is capable of "seeing correctly" a complex problem or of devising a good solution for it. Successful administration depends therefore upon obtaining the active assistance of technically competent people in defining problems, in devising solutions, and in following up the consequences. (1963: 309)

Note the overtones in the comments by Hower and Orth (1963) with regard to teamwork and skills of (project) team members.

Reward Systems

Certainly the aforementioned factors contribute to difficulties for engineers as managers. However, one other issue deserves attention, organizational reward systems. Soffron (1986) and Thornberry (1987) observed organizational systems of reward and promotion often appear to

force engineers into transitioning to management... even though they may not be prepared for management.

The dual ladder system of career progression as commonly recognized for engineers supposedly offers two equal paths for advancement and organizational rewards: the administrative (managerial), and the technical (Albright & Glennon, 1961; Kerzner, 1981; Meisel, 1977; Miles & Vail, 1960). However, only a few organizations claiming to provide such actually have two equivalent lines of progression with comparable rewards (Badawy, 1982; Cleland & Kocaoglu, 1981; Thornberry, 1987).

In fact, Badawy (1982) indicates the managerial path usually offers more appealing rewards, and those more often aligned with business society. Rewards for engineer managers generally involve a wider scope of activities commensurate with higher levels of responsibility and authority (Amos and Sarchet, 1981). Further, promotion criteria and job titles as part of the managerial path tend to identify more with business culture and business success (Badawy, 1982).

The result is many engineers are induced to seek out managerial jobs even though they may not be adequately prepared for such jobs (Badawy, 1978, 1982; Thornberry, 1987). Compounding the problem is the fact many organizations view the best technical professionals as the best candidates for manager's jobs (Badawy, 1978, 1982; Thornberry, 1987). Unfortunately, even the best technical people are not always the most suited for management (Amos & Sarchet, 1981; Badawy, 1982; Goshen; 1969).

> ... many technical managers are former technical professionals who, without any additional training, are vastly less competent at managing than their subordinates are at technical work. Attracted by what a management position

> offers, but without the will or the skills to manage, they are good candidates for failure. (Badawy, 1982: 44)

Moreover, Badawy (1982) citing research by Rosica (1972), reported technical professionals express much dissatisfaction about working for technical managers who are not as competent at managing as working in their technical field.

In a somewhat broader scope, the dual career ladder not only influences the transition of engineers to management, but the system also represents an effort to accommodate two different cultures of people (Badawy, 1982; Soffron, 1986). As Albright and Glennon (1961) have surmised, the dual structure suggests fundamental differences exist in career values and ambitions between technical and managerial personnel. In relation, Goshen (1969) concluded practicing engineers as a broad group are characterized by an enduring set of traits generally rewarded in engineering. Overall, because of the bias towards the managerial career ladder, the dual system seems to accommodate three groups of individuals:

- engineers who have essentially "engineer manager's characteristics"
- engineers inclined to remain engineers
- engineers for whom engineer manager's characteristics have no appeal, but go into management for the rewards or as a reward (Amos & Sarchet, 1981: 18).

Education of Engineers

While many authors are pointing out the apparent difficulties with engineers transitioning to management (Thornberry, 1987; Gadeken, 1986; Goshen, 1969; Hoffman, 1989; Lee, 1988), engineers themselves are also

doing the same. Despite the relative successes of Engineering Management as an educational discipline (Babcock, 1974), both engineering executives and engineering students continue to emphasize refining engineering educational programs to more adequately prepare engineers for managerial duties (Babcock, 1974; Badawy, 1978; Bennett & McMullen, 1987; Guteral, 1984).

Bennett and McMullen (1987) conducted one study in particular, aimed at determining the skills engineering employers wanted in engineering graduates. Surveys sent to 40 senior engineering managers and 133 graduates of an engineering and science program revealed oral and written communication, interpersonal relations, technical skills, and project management among the more important talents (Bennett & McMullen, 1987). As a matter of course, Bennett and McMullen (1987) recommended engineering schools consider these subjects in developing curricula and improving engineering management programs.

Similar recommendations resulted from a poll of engineering students conducted by Louis Harris & Associates Inc. (Guteral, 1984). Of the engineers surveyed, 64 percent identified the need to include more instruction on communication skills in undergraduate education and 67 percent reported human relations skills were not adequately taught in undergraduate engineering curricula (Guteral, 1984). More than 75 percent of the managers polled in the study also reported human-relations skills lacking in engineers (Guteral, 1984). At the same time, however, over 60 percent of the engineers surveyed agreed that undergraduate education provided an acceptable level of technical training (Guteral, 1984). Interestingly enough, while most engineers apparently believe it important

to keep technically up-to-speed in their professional discipline (Bennett & McMullen, 1987; Guteral, 1984), many advocate the best method of doing so is not through education beyond undergraduate schooling, but rather by actual work experience and participation-with-industry type programs (Guteral, 1984).

Managing Engineers

While on the subject of engineering management education and the skills employers desire of engineers (particularly those anticipating a move to management), it is worthwhile to note what engineers expect of their supervisors. Daugavietis and Harris (1976) performed one such investigation to examine whether supervising engineers differed significantly from managing non-technical personnel. The results were interesting.

In terms of subclassifications, technical competence ranked the highest overall among both engineer-supervisors (41 interviewed) and engineer-workers (72) as the item most descriptive of good supervision (Daugavietis & Harris, 1976). With subclassifications of characteristics grouped in more general categories, human relations appeared as one of the top two attributes of good supervision (Daugavietis & Harris, 1976). Among the items noted of poor supervision, inadequate communication ranked among the top two, as did human relations in the general categories established for the study (Daugavietis & Harris, 1976). In terms of relative importance compared to other skills and techniques believed necessary for supervision, human relations ranked number one for both engineering supervisors and engineers (Daugavietis & Harris, 1976).

Overall, Daugavietis and Harris (1976) concluded supervising engineers differed significantly from managing non-technical workers, in part because of differences in personal characteristics between the two. Moreover, the responses of non-technical supervisors included in the study (Daugavietis & Harris, 1976) appeared to highlight a lack of understanding on the part of nonengineers in how to best manage engineers.

Summary of Background

The previous sections in this chapter focused on achieving several purposes:

- providing a historical perspective of management studies
- highlighting the ambiguous nature of management studies
- identifying the progressive focus of managerial studies
- pointing out traits and skills reported to characterize effective managers
- establishing how a balance of personality trait and managerial skill theories appear to offer the best approach to developing effective managers
- revealing how differences in management environments, particularly between project and traditional management can place different demands on managers and perhaps require different skills
- examining engineers in management and trends for their increased involvement in project management
- underscoring the positive and negative aspects of engineers as managers and transitioning to management roles, indirectly establishing a basis for examining why certain trait and skill requirements may generally characterize project manager studies

- revealing the relationship between engineers' traits and skills and the areas emphasized in education and training programs to improve their management potential.

Overall, the review up to this point was aimed at establishing a comprehensive basis for examining the importance of technical competence among the various studies on project manager skills and attributes.

Project Management Studies

The subsequent review of project manager studies concentrates on investigating perceptions of the importance of technical competence and factors which may influence perceptions in the process of examining,

- the skills and traits reported to be required of project managers
- and how the importance of those skills and traits may vary as a function of individual and situational factors.

Numerous studies have been conducted and much written on project managers and projects (Cleland, 1988; Cleland & King, 1983; Cullen *et al.*, 1990; DiMarco *et al.*, 1989; Einsiedel, 1987; Eveld, 1978; Gaddis, 1959; Gadeken, 1989a, 1989b; Kerzner, 1982, 1984; Lock, 1969; Pinto & Slevin, 1989a, 1989b, 1988a, 1988b, 1987; Posner, 1986, 1987; Stuckenbruck, 1976a, 1976b; Thamhain, 1989). Among the many studies, the importance of many factors are stressed, especially in relation to various individual and situational elements which may influence project environments. One of the more prevalent factors emphasized is the importance of interpersonal skills to the project manager. Several issues seem to underlie the weight given this attribute.

As reported in the previous chapter, more and more project managers have engineering backgrounds (Lock, 1969). The emphasis on engineer-project managers, at least in the Department of Defense (Sanford, 1991), perhaps is a result of the technical character typical of military projects in several aspects (Table 3). Yet, the significance of technical problems which may characterize higher technology projects is much debated (Badawy, 1982; McCann, 1989). Further, even though technical expertise may be argued as the predominant qualification for some highly technical projects (Eveld, 1978), various authors suggest a project manager's technical knowledge alone is not enough to ensure effective and successful project management (DiMarco *et al.*, 1989; Dressler, 1986; Gadeken, 1989a; Randolph & Posner, 1988).

In point of fact, Rosenbaum (1990b) concludes human relations skills have become more significant overall as a result of the rapid advances in technology and more complex innovations. Given this supposition and considering the growing number of project managers with engineering backgrounds, the important issue indeed seems to involve people skills. As various studies indicate (Badawy, 1982; Gadeken, 1986, 1989a; Kerzner, 1981; Munson & Posner, 1979), often many project managers advancing from the technical ranks lack management training and adequate development of human relations skills; communication, integration, negotiation, and so on. Further, studies by several researchers (Gadeken, 1989b; Posner, 1987; Thornberry, 1987; Rosenbaum, 1990b) corroborate the lack, need, and significance of interpersonal skills among project managers.

TABLE 3

Differences Between Military and Civilian Projects

Military	Commercial
Cost not as important as performance of weapons systems	Highly cost-sensitive
Large ratio of technical to nontechnical personnel	Fewer technical personnel; less development, redesign, and emphasis on state-of-the-art
Most products custom-designed; tendency toward overdesign	Standardized, mass-produced products
Focus on state-of-the art technology	More emphasis on use of off-the shelf items to keep costs low
A relatively few customers, the U.S. government and its military services, which designate how a product is designed	Different customers with differing needs
Marketing and sales staff more dominated by engineers and other technical types	Concerns of marketing and sales personnel often override those of technical staff
Large, long-term contracts	Many customers, many orders
Much time spent on proposals and in developing documentation (operating and maintenance manuals)	Emphasis on specification sheets, instruction manuals, and warranties
During design and manufacture, a need to define a variety of missions; harsh, uncertain operating environment	Predictable product life is important
The customer-the the threat and mission requirements, while the contractor furnishes the technology; the two parties often work together to define a final work statement	Manufacturer of equipment supplies specifications
Documentation done concurrently, while job is underway	Documentation sometimes supplied after project completion

Source: Stix, G. 1989: 48. IEEE Spectrum.

Interpersonal Skills

In the process of researching ways to improve the program management course at the Defense Systems Management College, Gadeken (1989a) cited the work of several authors, Beck (1981), Gypen (1980), and McClelland (1984), who observed a general deficiency in interpersonal skills among technical managers.

Rosenbaum (1990b) too, highlighting research by Cougar and Zawacki (1980) (like studies by Beall & Bordin, 1964; Bennett & McMullan, 1987;

Brown *et al.*, 1981; Sarchet, 1969) revealed engineers may be technically qualified for project management roles but deficient in the interpersonal skills which generally characterize management (Brown, 1976). Rosenbaum concluded:

> Studies have shown that technical professionals tend to share certain aptitudes, some of which are highly compatible with the tasks of their occupation and others which are antagonistic to goal attainment. Technical ability appears to be more significant in determining early success, but interpersonal skills play a significantly more important role later on. With this in mind it is particularly disturbing that effective "people skills" for technical professionals are difficult to develop....(1990b: 24)

Recognize that Rosenbaum (1990b) suggests, somewhat indicative of Katz (1955), that technical skill is more important early on in a career (Figure 3).

In previous research, Amos and Sarchet (1981) also found certain skills, primarily people-related, become increasingly important and are greater sources of difficulty to engineer managers as they assume more management responsibilities (Table 4).

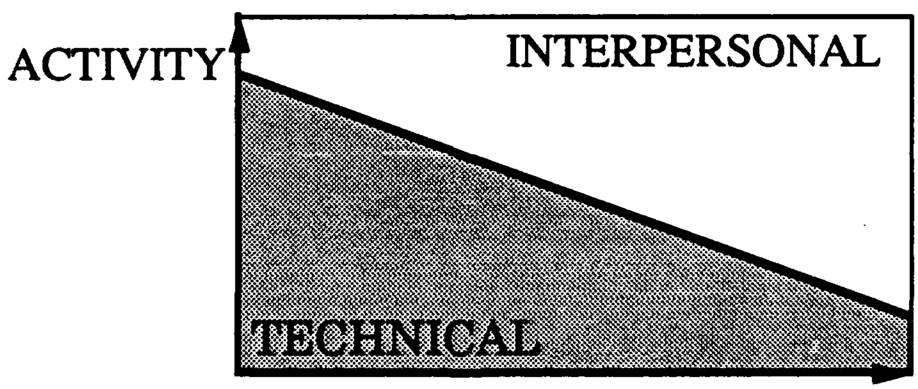


Figure 3. As Responsibilities Increase, Interpersonal Competence Becomes More Important to Success. (Source: Rosenbaum, 1990b: 25)

TABLE 4

Skills Required of Engineers Compared to Skills Required of Engineer Managers

Engineers	Engineer Managers
Solving technical problems Application of techniques Technical communication	Working within the organizational structure Fiscal analysis Dealing with personnel Working with people other than engineers Leadership Coordination Communications

Source: Amos, J. M., & Sarchet. B. R. 1981: 15. Management for engineers.

Additionally, in a study of 287 project managers, Posner (1987) obtained data partly validating the premier importance of people skills to some project managers. According to Posner (1987), if a project manager is a technical manager, or moving from a technical into a managerial position, often the need is for him or her to develop, acquire, or improve upon interpersonal skills:

> ... the primary problems of project managers are not technical, but human. Improving project managers' technological capabilities will be helpful only to the extent that this improves their ability to communicate, be organized, build teams, provide leadership, and deal comfortably with change. (1987: 54)

However, while it may be true the factors and variables most likely to cause problems in managing a project are human-related (Posner, 1987), it has not been shown by a preponderance of studies that solving people problems is the most consequential issue to the success of projects. Nevertheless, one particular study that does support a critical relationship between solution of

human relations issues and the success of a project was conducted by Thornberry and Weintraub (1983).

Thornberry and Weintraub (1983), in a previous study of 110 project managers and 8 high-technology firms, arrived at conclusions similar to those of Posner (1987) and Rosenbaum (1990b). Thornberry (1987) citing the study explains:

> In most high-technology firms project managers evolve from technical enclaves, especially engineering. But the skills needed to be a successful project manager almost are diametrically opposed to the skills and abilities desired and rewarded in an engineer.... People skills are perhaps the most difficult area for engineers to improve as they move into a project management position.... Our study indicated that interpersonal skills often spell the difference between success and failure for a project manager. (1987: 60)

Specifically, Thornberry and Weintraub (1983) identified 5 dimensions required for effective performance as a project manager: oral communications, influencing skills (leadership), intellectual capabilities, ability to handle stress, and work skills. Foremost among these, Thornberry and Weintraub (1983) found effective project managers achieved much of their influence over others through their interpersonal skills and use of negotiation and persuasion techniques.

Note also, in accenting the role of interpersonal skills, Thornberry (1987) reported the reward system common among engineers may contribute to the lack of people management skills. Albright and Glennon (1961), Goshen (1969), and Thompson, Bowden, and Price (1975) made similar observations in research on engineers (technical personnel) in general.

Interpersonal competence and the importance of human relations skills also appeared as a significant factor in the success of acquisition managers studied by the Defense Systems Management College (Gadeken, 1988, 1989a, 1989b; Gadeken, Cullen, and Huvelle, 1990).

As part of a multiyear multiservice research project involving interviews of 52 DoD acquisition program managers and a survey of more than 350 other acquisition managers, Gadeken (1989b) arrived at a 16-competency model to describe what it takes to be a good acquisition manager (Table 5).

TABLE 5

DSMC Program Manager Competency Model

Behavior Categories and Related Competencies			
Managing the External Environment	Managing the Internal Environment	Managing for Enhanced Performance	Proactivity
Sense of Ownership	Managerial Orientation	Long-term Perspective	Action Orientation
Political Awareness	Results Orientation	Focus on Excellence	Proactive Information Gathering
Relationship Development	Critical Inquiry	Innovativeness/ Initiative	
Strategic Influence		Optimizing	
Interpersonal Assessment		Systematic Thinking	
Assertiveness			

Source: Gadeken, O. C. 1989b. The right stuff: Results of DSMC's program manager competency study. Program Manager: 23.

A general review of each of the competencies identified by Gadeken (1989b) in Table 5 reveals a majority of skill areas which involve human relationships, building relationships and influencing people.

In sum, the studies by Posner (1987), Thornberry (1987), Rosenbaum (1990b), and Gadeken (1989b) indicate interpersonal skills are of premier importance to project managers. However, this conclusion is not without

limitations. Considering these studies were primarily conducted in high-technology firms, and most of the participants, if not all of those surveyed were technical experts, perhaps it is not very surprising to find that project managers require more human relations expertise. As Bennett and McMullen pointed out in a survey of 40 engineering managers, "Engineers, by education, experience, and choice, are specialists in the physical realm. They are not social scientists" (1987: 268). The point is it may not be totally acceptable to assume all project managers work in high-technology programs, possess technical backgrounds, and lack people skills.

Balance of Competencies

Several studies advocate a balanced perspective on skill requirements for project managers. Research efforts by Thamhain and Wilemon (1978), Cleland and King (1983), Kerzner (1984), and Thamhain (1989) for example, suggest a blend of skills are important to a project manager's effectiveness.

Based on field research and experience, Thamhain and Wilemon (1978) found effective performance as a program manager was a function of ability in 10 specific skills:

- Team building
- Leadership
- Conflict resolution
- Technical expertise
- Planning
- Organization
- Entrepreneurship
- Administration

- Management support
- Resource allocation (1978: 100).

Noteworthy, although concluding program managers cannot succeed with technical expertise or administrative skills alone, Thamhain and Wilemon (1978) assert, "...the program manager must relate socially as well as technically to understand how the organization functions and how these functions will affect the program organization of the particular job to be done" (1978: 100). Addressing technical competence in particular, Thamhain and Wilemon conclude:

> It is essential... the program manager understands the technology, the markets, and the environment of the business to participate effectively in the search for integrated solutions and technological innovations... without this understanding the integrated consequences of local decisions on the total program, the potential growth ramifications, and relationships to other business opportunities cannot be forseen by the manager. Further, technical expertise is necessary to evaluate technical concepts and solutions, to communicate effectively in technical terms with the project team, and to assess risks and make trade-offs between cost, schedule, and technical issues. This is why in complex problem-solving situations so many project managers must have an engineering background. (1978: 102)

Other authors support these findings. Kerzner (1982, 1984) for one, fully endorses the importance of the ten skills relative to effective program management, as well the role of technical expertise put forth by Thamhain and Wilemon (1978).

Cleland and King (1983) also advocate successful project managers, particularly those of complex systems have a blend of traits. Although the mix may vary depending on the type of organization, job level, or other situational factors, Cleland and King declare effective managers possess a combination of skills consisting of:

- an understanding of the technology of their business
- an understanding of the "basic concepts of management"
- an interpersonal style which facilitates their ability to get things done through others
- an ability to conceptualize and to operate using a systems approach (Cleland & King, 1983: 8).

Further, even though Cleland and King (1983) suggest, as Thamhain and Wilemon (1978), that managers can no longer succeed by relying solely on either personality or technical expertise, they likewise maintain a managers' ability to solve today's management problems characterized by uncertainty and complexity depends on technology know-how:

> In today's rapidly changing world, managers who do not know the technological base cannot possibly forsee future developments and relationships to other technologies. If they cannot do these things, they cannot effectively participate in the integration of their technology with others to provide the system solutions which are needed. More important, without this understanding they cannot forsee the future consequences of today's decisions. Thus, they cannot participate effectively either in taking advantage of current opportunities or in anticipating the future. Without such participation, they can only nurture the existing organization activities in the fashion of caretakers. (Cleland & King, 1983: 9)

In a later study Thamhain (1989) reiterated the importance of technical expertise to the project manager as part of a balanced basket of tools the manager should use to contend with a complex and rapid changing environment. In a field study of 220 project managers, and drawing from 15 years of personal observations, Thamhain concluded:

> What researchers find consistently and measurably is that project management requires skills in three primary areas: (1) technical, (2) administrative, and (3) interpersonal/ leadership... To be effective, managers must consider all facets

> of the job. They must understand the people, the task, the tools and the organization. (1989: 653)

With further regard to technical skills, Thamhain repeated the finding of previous studies (Thamhain & Wilemon, 1978), pointing out project managers need not always have all the technical skill required to "direct the multidisciplinary activities at hand" (1989: 653). Qualified project team members can and do bear responsibility for solution of technical issues (Pinto & Slevin, 1988b; Thamhain & Wilemon , 1987)

> It is essential, however, that the project manager understands the technologies and their trends, the markets, and the business environment to participate effectively in search for integrated solutions and technological innovations. Without this understanding, the consequences of local decisions on the total program, the potential growth ramifications, and relationships to other business opportunities cannot be forseen... (Thamhain, 1989: 653)

Other research efforts (Bloom, 1989; Carter, 1988; Einsiedel, 1987; Nicholas, 1989; Stallworthy & Karbanda, 1988) support similar perspectives on project managers, with considerations of technical expertise balanced in the context of various factors relative to the environment and resources characterizing a project.

Ernest Stallworthy and Om Kharbanda (1988) describe the road to success for project managers as dependent on a harmony of technical and interpersonal skills. Effective project managers are characterized primarily as generalists, managers capable of dealing with a multitude of disciplines which may be involved in a project, but who rely on the support of technically qualified subordinates to handle the technical project issues (Stallworthy & Kharbanda, 1988).

Likewise, Nicholas (1989) in a review of academic studies and reports published over the last 20 years on successful project management, also

endorsed the importance of a combination of human relations and technical expertise, while emphasizing how the need for technical competence may vary as a function of project characteristics. Successful (effective) project managers "were experienced and capable in administration, technology, communications, and human relations" (Nicholas, 1989: 25). Capable in technology generally implied it was adequate for the project manager to simply have an understanding of the technology involved in a project, but in high-technology projects the project manager needed to have a commanding knowledge of the technology (Nicholas, 1989: 25).

Research by Bloom (1989) also featured the significance of technical competence to the project manager and his or her ability to make decisions on technical issues, in addition to underscoring the importance of interpersonal skills. Bloom concluded the project manager should have several qualities to be effective:

- significant knowledge in the various aspects involved in a project
- ability to communicate with others about the project
- technical competence, at least to the extent of being able to understand technical issues, discuss, and decide technical solutions
- interpersonal skills (1989: 77).

Niwa and Sasaki (1983) likewise, advocated the need for project managers to have a combination of skills; including technical skills, which contribute to a multidisciplinary know-how. Niwa and Sasaki described these as:

- management skills
- technical skills

- economic and financial knowledge
- social and communication skills
- legal and political knowledge (1983: 65).

In other research, Carter (1988) introduces the importance of a capable project team as a source for skills, particularly technical skills. Carter (1988) described technical competence as an important factor relative to the effectiveness of project managers, but emphasized the need for project managers to rely on other sources of technical expertise besides their own. Carter (1988) concluded that project managers might afford to be less knowledgeable about the technology involved in a project if other individuals, like members of the project team, could be relied on to fill any personal void in technical expertise. According to Carter (1988), project managers should actively seek out and use the skills of others involved in the project, particularly technical specialists.

> The project manager's role is similar to that of an architect who must constantly select and use the skills of specialists to complete a task. The architect (project manager) cannot complete all these tasks alone but must orchestrate various skills to complete the project. (Carter, 1988: 13)

In fact, many authors (Einsiedel, 1987; Lock, 1969; Norko, 1986; Pinto & Slevin, 1989a; Thamhain & Wilemon, 1987) point out the ability of project managers to successfully manage a project does not always depend solely on the traits and competencies they possess. Other factors are or should be involved.

Einsiedel (1987) for one, considered the importance of factors external to the project manager in his profile of effective project managers. According to Einsiedel, "Often factors beyond the project manager's control affect the success or failure of a project more than the project manager's

efforts" (1987: 51). The fact projects are "leader-sensitive" (dependent on the project manager's performance) or "leader-proof " (where the project outcome depends more on situational factors), determines the approach which should be taken in selecting a particular manager for a project (Einsiedel, 1987: 51).

For leader-sensitive projects, Einsiedel (1987) declares it is important to select the right manager to complete a particular project, based on the requirements of the project leadership situation; the organizational structure and decision-making environment must be taken into consideration to choose the right project manager. A few situational descriptions are offered to illustrate.

First, temporary work organizations often established to motivate innovation in high-risk environments frequently prevent a project manager from using formal power and most of the manager's efforts are focused on acquiring information, resources, and technical expertise needed to make decisions (Einsiedel, 1987). Secondly, a project manager's ability to make decisions and choose among alternatives is often limited by available resources, skills, knowledge, and participation of others in developing solutions (Einsiedel, 1987). These two situations reflect how project characteristics may influence the desired attributes of a project manager. While emphasizing the importance of assessing these types of external conditions, Einsiedel (1987) offers a framework to evaluate project managers on the basis of five related qualities to help match the right manager to the right project in the context of situational factors.

Einsiedel suggests credibility (based on expertise derived from technical education, training, or experience, and trustworthiness), creative

problem-solver, tolerance for ambiguity, flexible management style, and effective communication skills are essential to effective program management (1987: 53). Selecting project managers in consideration of these factors and a project's level of leader-sensitivity appears to make it easier to determine whether it is better to change the project circumstances to fit the manager (Fiedler, 1965) or for the manager to adapt to the project (Einsiedel, 1987: 54). This outlook reflects flexibility in assessing what skills a project manager requires to manage a project effectively, and highlights why much variety may exist among project managers' required skills.

In underscoring credibility, Einsiedel (1987) also brings to light the potential importance in the relationship between a manager's technical competency and ability to influence others. Randolph and Posner (1988) introduce the issue:

> What people want most from project managers is honesty, competence, direction, and inspiration. These characteristics add up to credibility. When you are perceived as trustworthy, as knowing what you are talking about, as dynamic and sincere, and as having some sense of direction, others will see you as credible. When you have credibility, people tend to comply with your requests and to demonstrate a sense of commitment. (1988: 72)

Having credibility appears an important element, particularly considering credibility is a significant determinant of a project manager's leadership ability (Thamhain & Wilemon, 1978), and the ability of a project manager to obtain the support of other people involved in a project is a predominant factor in determining his or her effectiveness (Gemmill and Thamhain, 1973). In context, technical competency may be significant (Pettersen, 1991) as a potential source of authority to manage and lead personnel in support of a project.

Archibald (1976) reveals the sources of a project manager's authority. According to Archibald (1976), a project manager's perceived authority in leading a project is founded on a personal ability to earn such authority (commensurate with responsibility for the total project), in addition to authority assigned (legal authority). Legal authority, as Archibald (1976) explains, is derived from areas like organizational charter, position, and rank, while earned or personal authority evolves among other things, from technical knowledge. Cleland and King describe project authority similarly, in terms of *de jure* authority, the legal or rightful power in managing project actions, and *de facto* authority, derived from an individual's knowledge, expertise, interpersonal skills, or personal effectiveness (1983: 328). Further, Cleland and King (1983) indicate project managers typically lack *de jure* authority, and as a result must develop and rely on *de facto,* personal authority to be effective.

Recognizing project managers must often work across several functional areas and organizational lines to get the resources, services, and personnel support for a project, personal authority appears more critical (Gemmill & Thamhain, 1973; Thamhain & Wilemon, 1987). Cleland (1988) in fact, contends a project manager can expect to obtain more authority from knowledge (in addition to skill, personal effectiveness, and attitudes) than possible through the "legitimacy of an organizational position" (1988: 55). In short, the majority of a project manager's authority arises from his personal abilities (derived from technical and organizational knowledge, management expertise, etc) (Badawy, 1988). In this light, technical competency may contribute to a project manager's credibility and effectiveness.

Project managers are indeed, taken more seriously, viewed with more credibility, if they "possess the specialized technical education or training as well as a track record of successful project management relevant to the current project" (Einsiedel, 1987: 53). In fact, possessing specialized technical education or being attributed to having greater knowledge contributes to expert power, one of the three influence bases Wilemon and Gemmill (1971) identify from research as of major importance to project managers (Archibald, 1976: 44).

The possible importance of technical competency as associated with expert power is highlighted by the results of a study conducted by Carl Pitts (1990), using the Hersey and Nateymeyer Personal Perception Profile. This particular instrument is designed to "assess why someone responds to another's influence attempts" in terms of seven power bases: coercive power, connection power, expert power, information power, legitimate power, referent power, and reward power (Pitts, 1990: 22). Administering the profile to 146 project managers, Pitts (1990) found expert power ranked highest among the seven power bases. Outstanding project managers, those with a reputation for completing projects on time, within budget, meeting specifications, and whose team members would choose to work with on future projects given the chance, were recognized as powerful because they had a reputation for being knowledgeable about the project and ways to get it done (Pitts, 1990: 22).

In a similar study Hodgetts (1968) also investigated the techniques project managers used to overcome their "authority-gap" and improve their authority base. In interviews conducted with the participation of four types of firms, aerospace, construction, chemicals, and state government,

Hodgetts (1968) found technical competence, powers of persuasion and/or personality, and negotiation as the bases project managers use to overcome lack of formal authority. Relative to the other three factors, technical competence appeared the most important among all the firms except state government (Hodgetts, 1968). Using the results of the interviews in a follow-up survey of 56 organizations, Hodgetts (1968) obtained similar results. In particular, and perhaps of most potential applicability to DoD, 52 percent of the project managers in aerospace firms ranked technical competence as the most important to establishing authority (Hodgetts, 1968).

Gemmill and Thamhain (1973) also conducted a study on how project managers optimize support from project personnel, using the framework of interpersonal influence developed by French and Raven (1959). In a survey involving 136 personnel, expert power was ranked the number one factor in subordinates providing support to project managers.

Based on the findings of researchers like Hodgetts (1968), Gemmill and Thamhain (1973), and Pitts (1990), some importance may indeed be attributed to technical competence in association with a project manager being perceived as a leader, an expert, and having respect from others with a "reputation for being knowledgeable both about the project and about ways to get it done" (Pitts, 1990: 22).

Indeed, technical competence appears to play an important role not only in a project manager's ability to influence others, but also seems to be particularly significant to achieving project success in the overall context of team building efforts. Team building, as Thamhain and Wilemon (1987) describe it, is:

> one of the most critical leadership qualities that determines the performance and success of multidisciplinary efforts... projects critically depend on carefully orchestrated group efforts, requiring the coordination and integration of many task specialists in a dynamic work environment with complex organization interfaces.... It is especially crucial in a technical environment where projects are often highly complex and require the integration of many functional specialties in an often unconventional organizational setting.... (1987: 130)

Recognizing the significance of team building to project success, Thamhain and Wilemon (1987) conducted several studies over a four year period to identify drivers and barriers to team performance Several were found common (Table 6), as perceived by project professionals (Thamhain & Wilemon, 1987).

TABLE 6

Drivers and Barriers to High Project Team Performance

Drivers, Enhancing Project Performance	Barriers, Impeding Project Performance
• Professionally stimulating and challenging work	• Different interests and priorities among team members
• Professional growth potential	• Unclear project objectives
• Freedom to choose, decision-making	• Role conflict and power struggle among team members
• Good overall direction and leadership	• Excessive changes of project scope, spec, schedule, and budget
• tangible rewards	Lack of team definition and structure
• mutual trust, security, and open communications	• Wrong capabilities, poor selection of project personnel
• proper experience and skills	• Lacking commitment from team members or management
• sense of accomplishment	• Low credibility of project leader
• good interpersonal relations among team members and with management	• Poor communications
• proper planning	• Poor job security
• sufficient resources	
• Low interpersonal conflict	

Source: Thamhain, H. J., & Wilemon, D. L. 1987: 132. Building high performing engineering project teams.

Combined with the results of other studies conducted between 1974 and 1985, Thamhain and Wilemon (1987) concluded the primary drivers and barriers to project success were related to four main areas: managerial leadership, job content, personal needs, and general work environment. In particular, Thamhain and Wilemon (1987) found proper technical direction and leadership among the strongest determinants of successful team performance. Moreover, Thamhain and Wilemon (1987) reported the credibility of project leaders as critical to the leader's ability to effectively manage. Here again, technical competence may play a role in contributing to a project manager's effectiveness. As Thamhain and Wilemon (1987) explain:

> The effective team builder is usually a social architect who understands the interaction of organizational and behavioral variables and can foster a climate of active participation and minimal dysfunctional conflict. This requires carefully developed skills in leadership, administration, organization, and technical expertise. (1987: 134).

In addition to showing factors influencing team building, Thamhain and Wilemon (1987) also highlighted the importance of project managers knowing when various problems dominated the life cycle of a project. As Pinto and Slevin describe, "... the relative importance of various critical factors are subject to dramatic changes at different phases in the project implementation process" (1988b: 67). In other words, some factors are more critical to project success at different times during the various phases of the project life cycle (Pinto & Slevin, 1988b). In context, it is interesting to recognize if and when technical issues are a factor and how the importance of technical comoetence may vary as a function of project phase.

Several studies (Pinto & Slevin, 1987, 1988b, 1989a; Posner, 1986; Smythe & McMullan, 1975; Spitz, 1982) indicate technical problems are more prevalent, and hence technical competence more important during certain periods in the project life cycle.

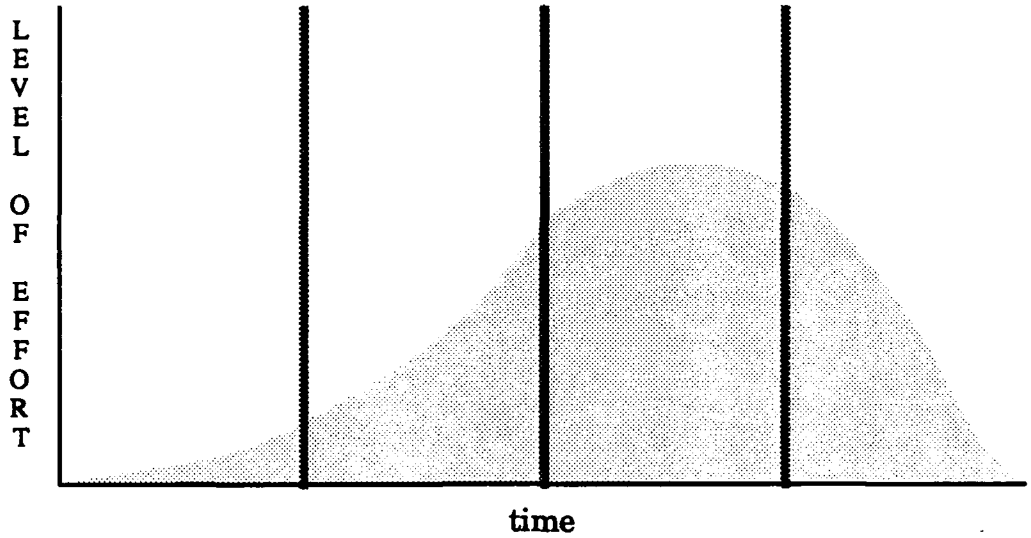
In a study involving more than 400 project managers, Pinto and Slevin (1988b) found the characteristics of the project team leader (competence administratively, interpersonally, and technically) to be one of the top five critical factors in determining project success (Table 7). Additionally, Pinto and Slevin (1988b) concluded leadership and the technical, interpersonal, and administrative competence of project managers appeared most consequential to project success during execution of the project (Figure 4). Moreover, Pinto and Slevin (1988b, 1989a) found technical tasks are more crucial to project success during execution phases of projects.

TABLE 7

Top Five Critical Factors Rated in Order of Ability to Predict Project Success

Project Success Factor	Description
Project Mission	Initial clarity of goals and general directions
Leadership/Characteristics of Project Leader	Competence of the project leader, administratively, interpersonally, and technically, and the amount of authority available to perform duties
Technical Tasks	Availability of the required technology and expertise to accomplish the specific technical action steps
Client Consultation	Communication, consultation, and listening to all impacted parties
Client Acceptance	Selling the final project to its ultimate intended users

Source: Pinto, J. K., & Slevin, D. P. 1988b. Critical success factors across the project lifecycle. Project Management Journal, 19: 67, 69.



Phase I Conceptualization	Phase II Planning	Phase III Execution	Phase IV Termination
Strategic need recognized, goals and alternatives for project established	Formalized plans established to accomplish developed goals	Actual work of the project is performed... materials and resources procured and transformed into intended project result	Project team disbanded, personnel reassigned, project transferred to intended users

Figure 4. Phases in the Project Life Cycle. (Source, Pinto & Slevin, 1988b: 69)

Smythe and McMullan (1975) arrived at comparable conclusions in a previous study of Air Force program managers. In an effort aimed at evaluating whether education, experience, and managerial trait qualifications of program managers varied as a function of the project life cycle, Smythe and McMullan (1975) found program managers reflected a dominant need for technical backgrounds (via education and experience) in the early stages of a weapons system program. Specifically, Smythe and McMullan (1975) concluded Air Force program managers needed an engineering background for effective performance during the Conceptual

and Validation phases (as defined by Air Force Regulation 800-2, Program Management, 1972) of the acquisition project life cycle.

Spitz (1982) too, found scientific/technical expertise to be perceived as the most important skill during the earlier project phases. In a study of project leadership among participants from a research and development organization, Spitz (1982) revealed indepth technical knowledge to be the most important element of project leadership during the Exploratory and Trial project phase (Figure 5).

From these studies (Pinto & Slevin, 1988b; Smythe & McMullan, 1975; Spitz, 1982) technical expertise appears more critical during the earlier phases of project life cycles (acknowledging differences in phase categorizations), but this may be partly related to the issues which seem to cause conflict over the life of a project. Conflict in project management has been the subject of various studies (Beck & Barth, 1976; Posner, 1986; Thamhain & Wilemon, 1975). Related findings have shown the ability to recognize the sources of conflict and manage conflict as crucial to a project manager's effective performance (Kerzner, 1982; Posner, 1986). Thamhain and Wilemon (1975) echo this in more fully describing the substance of conflict management in projects:

> ... conflict is fundamental to complex task management. Not only is it important for project managers to be cognizant of the potential sources of conflict, but also to know when in the life cycle of a project they are most likely to occur. Such knowledge can help the project manager avoid the detrimental aspects of conflict and maximize its beneficial aspects. (1975: 49)

What has been observed in studies of conflict (Baker & Wilemon, 1976; Posner, 1986; Thamhain & Wilemon, 1975) is a variety of potential causes,

in addition to a variance in the intensities of different causes across project lifecycles.

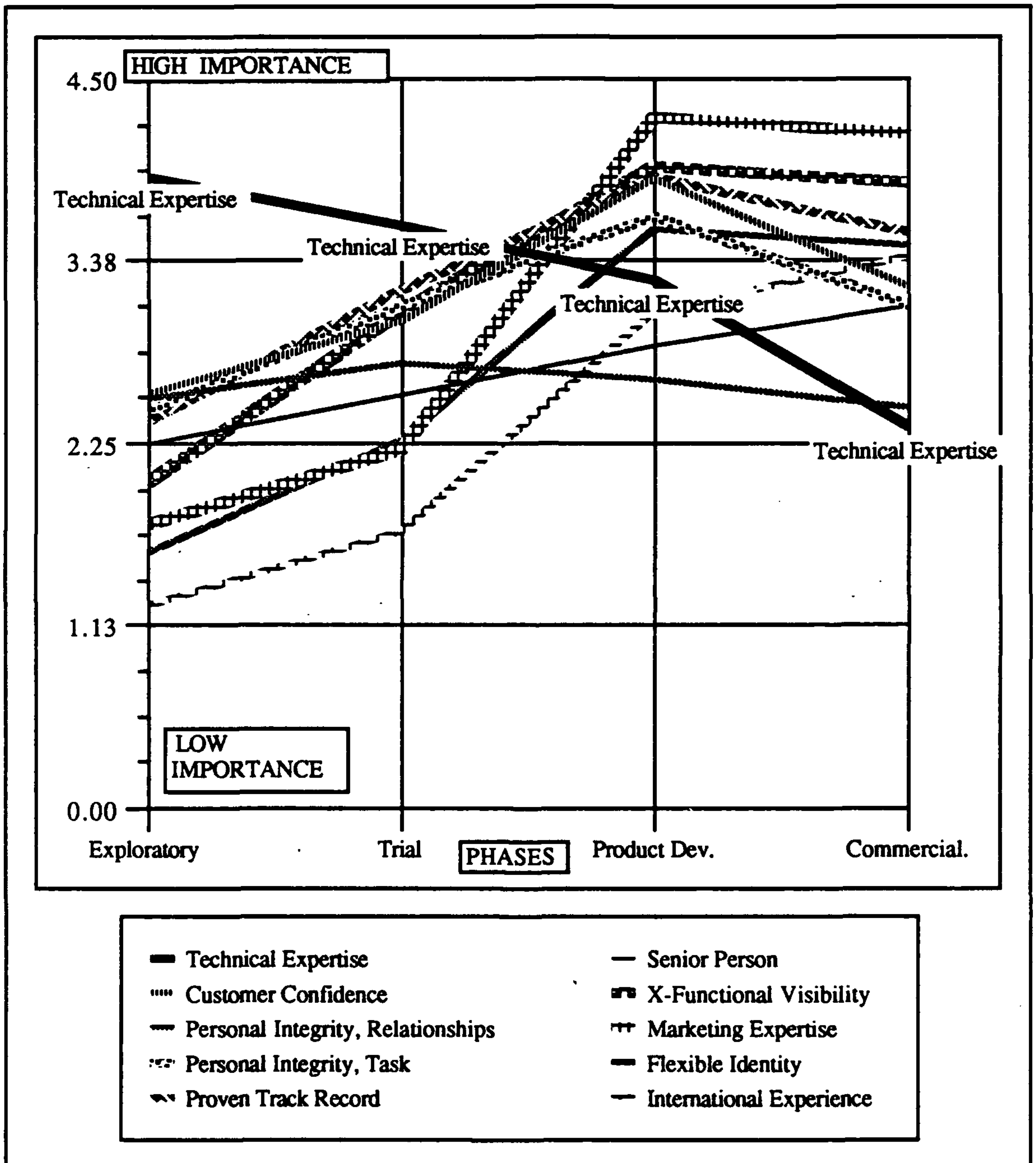


Figure 5. Mean score on importance of perceived skills over four phases. (Source: Spitz, 1982: 245)

In a study by Thamhain and Wilemon (1974) cited by Baker and Wilemon (1976), seven particular sources of conflict were revealed by project managers (Table 8). Note, conflicts over technical issues only ranked fourth overall (Baker & Wilemon, 1976).

TABLE 8

Potential Sources of Conflict
Rank-Ordered as Experienced by Project Managers

Conflict over:
Schedules
Project Priorities
Manpower Resources
Technical Conflicts
Administrative Procedures
Cost Objectives
Personality Conflicts

Source: Baker, B. N., & Wilemon, D. L. 1976. A summary of the major research findings regarding the human element in project management. Proceedings of the Project Management Institute, 8th Annual Seminar/Symposium: 68.

In a subsequent study of almost 150 project managers, Thamhain and Wilemon (1975) examined how these sources of conflict (Table 8) varied with regard to project phase. The investigation revealed the level of technical conflicts increased from the outset of projects, becoming most prominent during the main program phase before declining during project phase-out (Table 9). Posner (1986) achieved similar results in a survey of 287 project

managers. Conflicts over technical matters increased from the formation to project build up, and peaked in the main program phase (Posner 1986).

TABLE 9

Mean Conflict Intensities as Rank-Ordered Across Life Cycle Phases

Project Life Cycle Phases			
Formation	Build-up	Main Program	Phase-Out
project priorities	project priorities	schedules	schedules
administration	schedules	technical	personality
schedules	administration	manpower resources	manpower resources
manpower resources	technical	project priorities	project priorities
cost	manpower resources	administration	cost
technical	personality	cost	technical
personality	cost	personality	administration

Source: Thamhain, H. J. & Wilemon, D. L. 1975. Conflict management in project life cycles. Sloan Management Review: 31 - 49.

Comparing the results of these studies on conflict with those on the perceived importance of skills across project lifecycles is difficult. On face value, the findings do not indicate much of a correlation between level of technical conflict and the need for technical expertise. Perhaps situational differences between the studies contributed to the lack of agreement. Lack of a standard project life cycle phase structure among the studies may also account for limited correlation of results. Nonetheless, it appears at some time during a project, technical issues might be critical sources of conflict

and at some point project managers perceive technical expertise to be important to project success. However, the two circumstances do not necessarily coincide.

In addition to technical competence playing a possible role in a project manager's ability to resolve conflicts, it may also contribute in terms of education to a project manager's willingness to assume risk. Schenning (1989) conducted a study of Air Force acquisition managers with a focus on examining the role of risk in project management. Schenning (1989) concluded that program managers within the Aeronautical Systems Division perceived themselves as risk takers and believed risk was essential to be successful. Further, Schenning identified a slight bias toward risk taking by project managers with technical degrees versus those without (1989: 81). Additional research however, is required to assess the reason behind the difference, if one does indeed exist, and the tendency for managers with technical backgrounds to take more risks.

Overall, review of the literature appears to reveal the importance of technical competence, technical expertise or technical know-how by other names, varies. Before recapping the highlights it seems important, however, to recognize how technical competence may create problems for project managers.

Many authors (Kerzner, 1982, 1984; Lock, 1969; Thornberry & Weintraub, 1983; Wilemon & Cicero, 1970) point out a strong potential for technically competent project managers to be ineffective or fail as a result of their technical capabilities. As Kerzner explains, project managers appointed from the ranks of "Technical specialists may not be able to divorce themselves from the technical side of the house..." (1984: 177).

Reluctance to "give up doing the technical things they knew best" and delegate the work to other team members makes such project managers ineffective (Thornberry & Weintraub, 1983: 75). Wilemon and Cicero elaborate:

> The greater the project manager's technical expertise, the higher the propensity that he will overly involve himself in the technical details of his project. The greater the project manager's difficulty in delegating technical task responsibilities, the more likely it is that he will over involve himself in the technical details of the project. (1970: 277)

The sentiments of a project team member in such a situation are recalled by Wilemon and Cicero:

> I've had experiences where I felt that the project manager was trying to exert too much influence in the technical areas in an attempt to make the decisions himself... that's what his project team is for.... (1970: 277)

Consequently, "if the project manager overstresses his technical function, it may have the effect of usurping the supporting research and development (technical) commitments and concomitantly creating a technical imbalance" (Wilemon & Cicero, 1970: 277). The result of an imbalance in managerial and technical focus then, appears to be ineffective use of human resources and an overall detrimental effect on project success.

Although technical competence may prove fatal to some project managers, it also seems of some significance, especially to those who may not have technical academic backgrounds or experience. As such, it may be worthwhile to note what project managers consider as the best means of becoming effective project managers, particularly with regard to developing technical competence.

To begin with, academically, prospective project managers are most likely to be exposed to project management concepts and principles as part of the curriculum within collegiate Engineering departments (Cook & Granger, 1975). Thereafter, Stuckenbruck((1976) indicates successful project managers develop via experience, especially through some type of apprenticeship in project offices. Working as assistants, good project managers learn the ability to view complex projects in broad perspective, as well as acquire working knowledge of all the various disciplines critical to success in their projects (Stuckenbruck, 1976). Thornberry (1987) advocates apprenticeship too, but apprenticeship which includes on-the-job training. Using on-the-job training in this way better ensures the apprentice manager not only understands a job, but can do the job as well (Thornberry, 1987). Thamhain and Wilemon promote a similar development process, where technical expertise needed for effective management is achieved by experience in several projects in a specific technology area (Thamhain & Wilemon, 1978: 102). Randolph and Posner (1988) have a more narrow focus and report individuals learn the most about becoming effective project managers from experience. Pettersen (1991) advocates a combination of several approaches, emphasizing the importance of experience and on-the-job training achieved via incrementally performing different jobs at different levels.

Summary of Literature

The primary focus of this section of the literature review was to provide an examination of the findings relative to the various skills and attributes considered important to effective performance as a project manager, and in

the process point out propositions on the importance of technical competence and factors which may influence the importance of technical competence. Certainly a variety of views exist, but overall the prevalent supposition resulting from the many studies is that technical competence may indeed be important, but probably is just one among a balance of several skills contributing to effective performance. The level of importance, however, is a point of contention (it appears). Project technology, level of management responsibility, qualifications of project teams, educational background, and phase of project lifecycle all appear to influence the level of importance which may be attributed to technical competence. Further, the significance of technical competence appears to increase in the context of different organizational situations where credibility may determine a majority of a project manager's authority base.

With these results in mind, one objective of this study is to validate a group of factors as potential sources of influence on the perceptions of the importance of technical competence, and to examine how acquisition managers' perceptions of technical competence vary as a function of these factors. Appendix A provides tables summarizing several of the studies reviewed in the literature on project managers.

III. Method

Overview

This chapter describes the research methodology used in this study, beginning with a description of the research design. Then the discussion explains the data collection method and development of the collection instrument used in the study. Details of the pilot study conducted to develop the data collection instrument are also included. Sections thereafter provide information on reliability and validity considerations, the study population, the sample, the methods used to examine data, and research assumptions (not otherwise addressed).

Research Design

Many leading authors of research methodology provide definitions for "research design," each capturing some similar but in general a variety of different aspects. It is a complex concept. In the most basic sense, however, the research design of a study represents a plan for identifying sources of data relevant to the research, and a strategy for collecting and analyzing the data (Emory, 1985). Inherent in research design lie two basic purposes: providing answers to research questions, and controlling variance (Kerlinger, 1973: 300). The design, if appropriate, allows a researcher to obtain answers to research questions which are as valid, accurate, and objective as possible and at the least practical cost (Kerlinger, 1973). In context, the research design of the present study may be described in several perspectives. The ensuing sections establish the research design of this study in terms of classifications characterizing the design, the

research strategy, and the actions taken to ensure the design supported investigation of research questions while controlling variance.

Design by Classifications

Using classifications provided by Emory (1985), this research represents an exploratory effort, by survey, of ex-post facto approach, descriptive in purpose, cross-sectional in time, of statistical scope, and within a field environment.

As an exploratory field study, the research primarily focuses on finding relationships rather than predicting relationships among study variables (Kerlinger, 1973). As a survey in design, the study reveals data collection by questioning (potential respondents) and indicates no control exists over variables--the ex post facto characteristic. In ex post facto research, the researcher has no direct ability to manipulate variables (except possibly by introducing bias perhaps a result of using inadequate or inappropriate sampling procedures) (Emory, 1985; Kerlinger, 1973). Without such control, findings should follow as a result of what has happened or what is happening in the research environment. Here, the study is descriptive. The purpose of the research primarily concerns determining the relationships among study variables (Emory, 1985). In terms of time and scope, the study is cross-sectional since it is basically performed once, and statistical, considering a broad cross-section of data is sampled from the population of acquisition managers at Wright-Patterson Air Force Base. With regard to research environment, the study embodies a field study where subjects provide information under normal, life situations as opposed to simulated conditions typical of laboratory studies

(Emory, 1985, Kerlinger, 1973). Compared to laboratory studies, the variance of variables supported by a field setting is ordinarily large. The increased variability serves to cause greater differences in dependent and independent variable relationships which enhance the external validity of results (Cook and Campbell, 1979; Kerlinger, 1973).

Part of the research design includes strategy, the means used to gather data and analyze research data (Kerlinger, 1973). The next sections address the research strategy for this study in terms of the data collection method, development of data collection instruments, and description of the study population and sample.

Data Collection Method

A questionnaire in the form of a mail survey was chosen as the method to acquire the data needed for this research. Many authors agree (Emory, 1985; Fowler, 1984; Parten, 1966; Ross, 1988), mail surveys offer several advantages compared to some other methods of securing information: lower costs, potential to obtain a larger and more representative sample, and the ability to contact respondents who might otherwise be inaccessible. Further, mail surveys allow informants to respond more honestly because of anonymity, give respondents the chance to answer at their convenience, and permit all respondents to receive the same questions which reduces potential for one form of bias. These benefits weighed heavily in favor of the mail survey during determination of a data collection method. In consideration of several factors: the desire to collect a large number of respondents to support sampling reliability (Parten, 1966); from a population of individuals generally very busy, frequently unavailable, and of

various ranks; within a limited amount of time, and; at the least possible cost, questionnaires indeed seemed the most beneficial means of data collection. However, other methods were considered.

A qualitative research methodology may have supported a rigorous examination of the importance of technical competency in the social settings of acquisition projects, especially with regard to factors influencing the importance of technical competency. Unfortunately, constraints prevented the opportunity. As Soffron states, "qualitative research methods are grounded in, and emerge from, directly observable social data--the observed social phenomena" (1986, 124). The time was simply not available to undertake such an approach and acquire first-order data from direct observations of acquisition managers. Other methods may also have been used. Interviewing for example, was considered as a data collection approach.

Interviews accord some advantages, including high response rates and the ability to clarify complex issues with respondents (Emory, 1985; U.S. Army Research Institute, 1989). However, interviews typically require a large amount of time. The period of time available for this study seemed to prohibit conducting the number of interviews required to obtain a representative sample large enough to draw valid conclusions about the variables in this study. Additionally, the concept of technical competency was not believed to present the potential for misunderstanding which might warrant an interview approach. Further, when compared to mail surveys, interviews guaranteed no measurable difference in results. In fact, Fowler states, "Overall, when samples are comparable, researchers have found that most survey estimates are unaffected by the mode of data collection"

(1984: 66). With this in mind and taking account of the aforementioned factors, the mail survey presented the best choice of data collection methods.

Development of Data Collection Instruments

Survey development followed a semblance of the process (Table 10) outlined by Sheard and Gnauck (1976). After establishing the objectives for the study and the research questions to guide the effort, instrument development began with a determination of the content areas to be embraced in the survey. By a process of brainstorming and searching the literature, an effort was made to investigate all the possible content areas which might be included in the study.

Brainstorming involved participation of four acquisition managers cognizant of the research topic in generating ideas about potential content areas. In an informal discussion, the group suggested several possible content areas for the study:

- how the perceived importance of technical competence varies relative to:
    - •• educational background
    - •• engineering experience
    - •• acquisition experience
    - •• technical expertise of project teams
    - •• level of project technology
    - •• acquisition phase.

TABLE 10

Characterization of the Questionnaire Construction Process

Steps	Mechanism	Examples/Criteria
Determine Content Areas	Brainstorm Literature Review	Technical Academic Training
Select Content Areas	Logical Choice	
Develop Items	Logical Choice Given Objective	Open-ended Checklist Ranking Rating Multiple Choice Attitude
Develop (First Draft)	Logical Grouping of Items Instructions Critique (Revision)	
Pilot Test (Second Draft)	Analysis Revision	Answerability Response Mode Useability
Preparation (Final Draft)	Logical Organization Planning and Control	

(Sheard and Gnauck, 1976: 31)

A follow-up discussion with a more experienced acquisition manager helped assess whether each of these would be useful and relevant to the study. However, final determination of potential content areas did not occur until after a thorough search of the literature.

Review of past studies on project managers and acquisition managers revealed several content areas considered by others in research similar or related to the study at hand. Although disclosing a few additional candidates for content areas, for the most part the search of literature simply corroborated the areas identified during brainstorming. Final selection of study content areas occurred after organizing and classifying the areas using four criteria proposed by Lazarsfeld and Rosenburg (1965) (Sheard and Gnauck, 1976: 31):

• Articulation: The classification proceeds in steps from general to the specific allowing examination of material in either broad or detailed groupings, whichever may be more appropriate.

• Logical correctness: In an articulated set of categories those on each step must be exhaustive and mutually exclusive. When an object is classified from more than one aspect, each aspect must have its own unique set of categories.

• Adaptation to the structure of the situation: The classification should be based on a comprehensive outline of the situation as a whole, containing the main elements and processes in the situation which it is important to distinguish for the purposes of understanding, predicting, or policy-making.

• Adaptation to the respondent's frame of reference: The classification should present as clearly as possible the respondent's own definition of the situation, focus of attention, and categories of thought.

Organizing the potential content areas using these criteria made it easier to determine the categories the study should encompass in support of the research objectives. Those believed to be within the scope of the research objectives were included and subsequently represented by appropriate questionnaire items.

Initially, the set of questions developed for the study reflected a few shortcomings. A pilot test of the first draft among a sample of graduate students (n= 23) with a variety of prior experience as acquisition managers revealed weaknesses in areas Sheard and Gnauck (1976) describe as completion time, the answerability of questions, response mode of survey items, and useability of resulting data. Several modifications resulted.

First, feedback from the pilot test indicated a need to reduce the completion time. Because the multiple choice format required several questions to obtain rankings of multiple items within individual content

areas, completion time for the instrument took from 20 to 35 minutes. A majority of respondent's in the pilot test claimed the questionnaire took too much time and became rather monotonous before they finished half the questions. Alternately, adopting to a rank ordering allowed one question in many instances to achieve what previously required several multiple choice items. So revised, the shortened survey required on average no more than 10 minutes for respondents to complete. Respondents in a follow-up test indicated the revised survey not only seemed more aligned with their education level and verbal ability, but generally agreed the instrument better accommodated the nature of their job. That is, many of the acquisition managers felt a shorter survey would motivate a higher response rate considering they normally had little time available to complete a survey. Many authors (Fink & Kosecoff, 1985; Ross, 1988; Sheard & Gnauck, 1976) in fact, suggest a shorter questionnaire can make respondents more willing to pay attention to the survey and support a higher response rate. Note, however, some (Dillman, 1978; Emory, 1985; Parten, 1966) do not agree, and suggest nc significant evidence exists to support the view shorter surveys obtain higher response rates. In general, this proposition may be true for the environments characterizing the majority of mail surveys. Nonetheless, this study assumes such is not the case and that the former situation holds true within the military acquisition community at Wright-Patterson Air Force Base.

The second concern involved answerability. Review of the pilot test results revealed a few of the same questions were left unanswered by a number of respondents. This suggested the need for some revision, either to the stem of the particular questions posed, the mode of response

(the third source of potential problems), or the instructions. Using respondents' feedback, items reported as ambiguous or inconsistent were consequently revised. Additionally, in the process of rewording questions and rating scales, steps suggested by Guilford (1954) were taken to reduce the potential for the errors of leniency, central tendency, and the halo effect. Again, results of the follow-up test with the revised draft survey showed satisfactory improvements. Rank-order formats cut completion time and made answering questions more convenient. The improved response mode and addition of examples depicting the correct methods of responding to questions in the study appeared to eliminate occurrence of unanswered questions.

Useability of resulting data construed another basis for difficulties. Not only were questions left unanswered with the initial draft, but some answers obtained during the pilot test proved unuseable as a result of informants giving answers in the wrong form. The aforementioned improvements in the instructions and response mode seemed to remedy this problem. In addition, use of design tables (Kerlinger, 1973) in clarifying the research problem and guiding reconstruction of survey questions helped establish an improved layout and item sequence for the questionnaire. Questions were grouped and ordered along guidelines provided by Emory (1985) to motivate respondent interest and participation, and to acquire the fullest possible range of desired information.

Additionally, the response structures for three of the rank-order questions in the revised draft, all central to the study, were redesigned. Each of these questions (6, 8, and 9) required a rank ordering of choices which were randomly ordered and left unnumbered to prevent order bias

(Emory 1985). In fact, two separate versions of the questionnaire were eventually prepared to minimize order bias and support assessment of reliability. Specifically, the ordered choices of response for questions 6, 8 and 9 were exactly reversed between the two versions of the final survey.

Overall, the revised survey, even though reduced in length, still addressed the same personal and situational variables relative to the hypotheses put forth for this research. However, reducing the questionnaire length potentially reduced the ability to verify the reliability of the survey instrument (Guilford, 1954). Nonetheless, efforts were taken in several areas, some already mentioned, to improve and measure reliability of the developed instruments.

Reliability. Reliability is the relative absence of errors of measurement in a measuring instrument (Kerlinger, 1973); the extent questions provide consistent measures in comparable situations (Fowler, 1984; Weisberg & Bowen, 1977). In a broader sense, reliability encompasses several aspects: adequacy of samples in terms of size and representativeness, as well as the accuracy of measures achieved by a measuring instrument (Kerlinger, 1973; Parten, 1966; Remmers, 1954). For this study, actions were taken in context of each of these areas to promote achieving a satisfactory level of reliability.

Although indirect in instances, previous sections on the development of the data collection instruments pointed out efforts to promote reliability and reduce random error relative to instrument design. Table 11 summarizes these. The next section describes the steps performed to assess the reliability of the data collection instrument.

TABLE 11

Methods Used to Further Reliability of Results by Instrument Design

Potential Source of Random Error	Step Taken to Ensure Consistent Measurement
Inadequate Wording of Questions	Questions must be written fully and not confuse respondents which would require them to add/change words in order to construct an answerable question (Emory, 1985; Fowler, 1984; Parten, 1966; Ross, 1988). Feedback via a pilot study supported efforts to provide concise, well-constructed questions without biased wording or emotionally charged phrases; and clear instructions to prevent alternate means of answering questions.
Inconsistent Meaning of Questions	Questions must mean the same thing to every respondent (Dillman, 1978; Emory, 1985; Fowler, 1984; Kerlinger, 1973; Parten, 1966; Ross, 1988). Use of a pilot study allowed any ambiguous terms to be more clearly defined, especially those capable of multiple meanings. Rewording emphasized use of neutral terms, simple, familiar, and commonly used among respondents.
Dishonest Responses	Untruthful answers can be controlled using internal checks (Parten, 1966) and official sponsorship (Ross, 1988). Sponsorship by the functional manager of all acquisition managers at WPAFB was obtained. Further, factual data reported by respondents were randomly compared to objective data available.
Differences in Perception of Adequate Responses	Respondents must have the same perceptions of adequate answers to items to avoid bias (Dillman,1978; Emory, 1985; Fowler, 1984; Parten, 1966). Emphasis was placed on designing alternatives to cover the fullest range of possible responses and expressing responses to questions as explicitly as possible.
Sequence of Questions	A pretest of the question ordering was accomplished as part of a pilot study. Using inputs from the pilot study and suggestions of various authors (Dillman, 1978; Emory, 1985; Fowler, 1984; Parten, 1966; Ross, 1988) questions were ordered to motivate participation, provide a logical flow, and to preclude any similar questions from influencing one another.

Several common methods exist for determining the internal consistency of a measuring instrument, including the test-retest, alternative forms (parallel tests), and the split-half. These are basically distinguished in terms of two perspectives: stability (consistency over time), and equivalence (consistency at a point in time among observers and samples of items) (Emory, 1985). In general, the test-retest represents a measure of stability, while alternative forms and the split-half techniques measure equivalence (Emory, 1985). In this research, the test-retest and

parallel tests methods characterized the reliability measures performed on the measurement instrument.

Test-Retest. The test-retest involved correlation of the results obtained from two samples (n=23) taken more than 30 days apart among the same respondents. Both versions of the revised questionnaire that evolved from the pilot study were used to perform the test-retest. For the test, every other respondent received the same version of the instrument. In the retest, respondents received the alternate version of instruments completed during the test. Recall the differences between the versions simply constituted a reverse ordering of items to be ranked for questions 6, 8, and 9.

Of the 23 individuals sampled during the test with the revised instrument(s), only 19 completed the retest. Using each of these individual's rankings of items for questions 6 and 9 in the two samples, rank-order coefficients of correlation (Kerlinger, 1973) were calculated. Questions 6 an 9 were chosen for use in assessing internal consistency because (1) they constituted a major part of the research, and (2) each involved alternate forms of the same responses for identical questions. Overall, the individual correlations averaged to a value of .81 for question 6 and .86 for question 9. These values implied respondents were not randomly giving responses to the questions on the surveys. Further, with few exceptions, review of responses to multiple choice questions (most factual data) revealed no differences between test and retest. Other measures also provided indications of reliability, as will be discussed. First, however, some of the shortcomings of the test-retest deserve mention.

While the average correlation-coefficients calculated for the 19 respondents answers generally reveal a positive correlation between test

and retest, the results warrant caution. The limited sample size does not guarantee a representative measure of reliability. Additionally, the time between test and retest can affect the results obtained (Emory, 1985; Kerlinger, 1973; Parten, 1966). Performed too soon, respondents may remember answers and repeat them. On the other hand, the longer the time between test and retest, the greater the potential for some situational factor to alter a respondent's attitudes or opinions about the subjects questioned. The result in both cases is the same--bias, although to the positive in the former and to the negative in the later case ((Emory, 1985; Kerlinger, 1973; Parten, 1966). As a result of these weaknesses in the test-retest technique, interest centered on other methods which might support a more robust assessment of reliability.

Comparable Sample Comparison. Although not yet described, the overall sample obtained for this study actually represented two simultaneous subsamples of equivalent composition, one employing one version of the survey and another using the second version. This scenario resulted from providing every other respondent randomly selected in each stratification base (explained in Sample Description) the same version of the survey. Two comparable samples (n= 113 [115 with two cases deleted] and n = 113) for use in reliability tests were then achieved. By measuring the correspondence between the results from two such samples, the level of confidence attributable to findings could be determined (Parten, 1966). As Fowler explains, the distribution of answers to a subjective question only has meaning when differences between samples exposed to the same questions are compared (1984: 97). The greater the correspondence between results from the two samples (represented by two versions of the survey),

the more confidence may be placed in the findings (Parten, 1950: 496). Kerlinger (1973) in fact, cites a classic study by Stouffer (1955) as an example. "By using two separate samples, not only could external and internal checks of survey data be made; the results of one survey could be checked against the other..." (Kerlinger, 1973: 419).

Based on this methodological approach, the correspondence between randomly selected variables in the study were measured to assess the consistency of responses between the two subsamples and overall reliability of the survey instruments. Rank-order correlation coefficients (Kerlinger, 1973) served as the basis of me·.sure. Overall, the correlation analysis of responses for similar questions in the two data collection instruments indicated a satisfactory level of reliability in terms of consistency. Figure 6, as an example, shows a comparison (in terms of relative frequency distributions) of the responses to question 5 for the two survey versions.

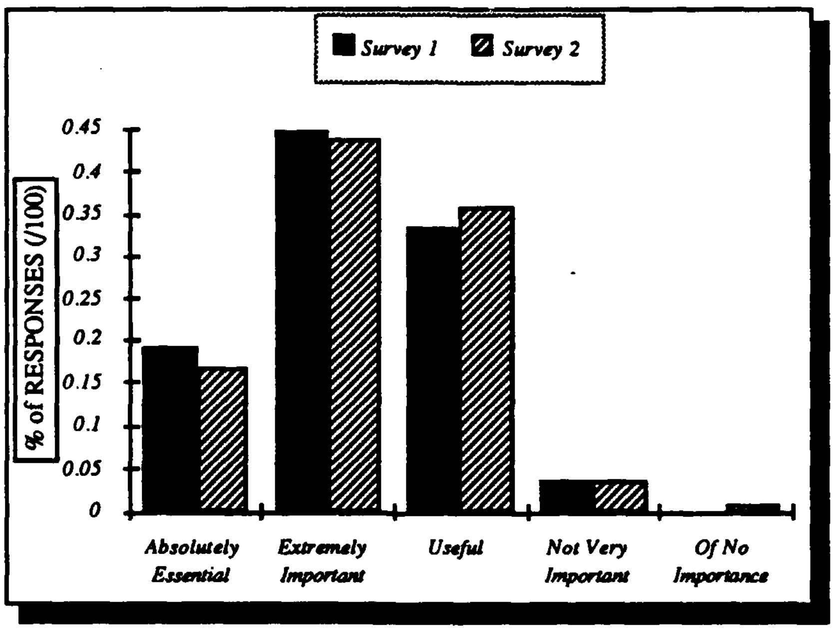


Figure 6. Comparison of Survey Distributions on Responses to the Perceived Importance of Technical Competence

Validity. While good questions provide consistent answers in similar situations, valid questions provide answers which correspond to what they are actually intended to measure (Emory, 1985; Fowler, 1984). Beyond acknowledging reliability contributes to validity (Emory, 1985), assessing validity of the measurement instrument in this study posed a few challenges. The research focused on obtaining factual information, and a substantive portion of subjective responses indicating perceptions. The validity of the factual reporting presented the least difficulty.

Because objective data was available on respondents, confirmation of some factual responses was indeed possible. *Reports on Individual Personnel* and a source listing of acquisition managers allowed a random crosscheck of data on educational accomplishments, job experience and to some extent project technologies. No evidence existed to show any measurable differences between records and related responses on surveys.

Assessing the validity of subjective questions presented a greater challenge. Without an external criterion, only estimates of the validity of subjective measures are possible (Fowler, 1984). Judgement of validity is based on the extent responses meet expected levels of association with individual or situational characteristics with which they should be related (Fowler, 1984). The reliability of questions and representativeness of the content of the measuring instrument then, become critical determinants of validity.

To the extent subjective questions are unreliable, their validity is reduced (Emory, 1985, Fowler, 1984). Efforts to standardize meaning among questions and eliminate ambiguous wording in this study were

expected to minimize the opportunity for such. In addition, actions taken to identify the content areas for questions focused on providing representative and comprehensive coverage of the factors influencing perceptions of technical competence. Based on the review of literature and evaluation of questions by experienced acquisition managers viewed as competent judges (Parten, 1966), the content validity of the study was assumed satisfactory.

Of all the potential aspects of validity in this study, construct validity perhaps represents the most important. This is because the study aims to determine which factors or constructs account for variance in the perceived importance of technical competence. In effect, the research seeks to find the amount of variance in perceptions which is accounted for by the various constructs: technical academic training, level of project technology, acquisition experience, etc. Assessment of construct validity for this study, therefore, involved testing of the research hypotheses (Kerlinger, 1973).

For example, the testing of Hypothesis # 11 reflected use of the *known-groups* method (Kerlinger, 1973; Parten, 1966) to assess construct validity. In this technique, groups of people with known characteristics or expected biases (in the judgement of competent persons) are given a survey to determine the ability of the instrument to reveal the biases. The extent the survey reveals the bias, attitudes, or characteristics indicates the validity of the instrument (Kerlinger, 1973; Parten, 1966). As the test of Hypothesis # 11 reveals in Chapter IV, the groups of acquisition managers with the most technical academic training, predisposed to perceiving technical competence as important, indeed proved to consider technical competence more important than other groups, especially those expected to view technical competence less important. The survey differentiated the two

groups based on the statistical test employed. The ability of the survey to distinguish the groups in this way indicates a positive level of discriminant validity, one type of construct validity evidence (Kerlinger, 1973).

Nonresponse Bias. While discussing validity and assessing bias, the subject of response bias deserves attention. Nonresponse is one of the potentially significant drawbacks of mail surveys (Dillman, 1978; Emory, 1985; Fowler, 1984; Kerlinger, 1973; Parten, 1966; Ross, 1988). Usually individuals not responding do not differ much from those who do respond (Weisberg & Bowen, 1977), but the greater the level of nonresponse, the more important it is to determine if those not responding are different and perhaps concentrated among a certain group in the population. The issue centers on representativeness, and whether those refusing to respond may have answered significantly different from those who did (Emory, 1985). Simply put, the credibility of the research and the ability to make valid generalizations are at risk (Kerlinger, 1973; Parten, 1966).

Unfortunately, despite a multitude of actions which may improve response and lessen the capacity for bias, a certain number of nonrespondents usually cannot be prevented (Fowler, 1984; Parten, 1966). The characteristics of groups solicited to participate (Fowler, 1984; Parten, 1966; Ross, 1988), the level of interest in the research topic (Fowler, 1984; Parten, 1966), the influence of sponsorship (Emory, 1985; Parten, 1966), general appeal of the survey (Fowler, 1984; Parten, 1966), and the extent of agreement with any propositions put forth about the survey topic (Parten, 1966), all affect the number of responses obtained. Other special circumstances may also influence response rate.

For one, individuals randomly selected from a list may no longer be identified with the group of people on the list solicited to participate (Parten, 1966). As in the case of this study, a few questionnaires were returned as a result of individuals relocating to new jobs. The possibility for people being ill, on vacation, or absent due to business travels may also prevent returns. In particular, the significant number of temporary duty assignments characterizing many acquisition managers' jobs may have had a bearing on the number of nonresponses in this research. If, however, these events are assumed to be randomly distributed across the variables measured by the questionnaires, none of these had a potential to seriously bias results.

Nonetheless, in addition to design considerations intended to improve participation in this research, several other actions were taken to motivate a satisfactory response rate. One step taken to minimize the number of nonreturns involved soliciting sponsorship (Emory, 1985; Ross, 1988; Parten, 1966) by ASD/CY and approval of the survey by the Air Force Military Personnel Center (AFMPC).

ASD/CY, the Deputy Chief of Staff, Program Management and functional manager of all program managers at Wright-Patterson AFB was contacted and subsequently agreed to sponsor the questionnaire. After ASD/CY approved the questionnaire package and signed the cover letter on 11 Jun 91, the surveys (both versions) were hand-carried to the base survey control officer with a request for approval in accordance with Air Force Regulation 30-23(C1), Air Force Personnel Survey Program. (Note, design of the cover letter incorporated some degree of objective disguise (Emory, 1985) to reduce potential bias)

Subsequently, the base survey control officer contacted the officer in charge of the Military Survey Branch (MPCYPS) at the Air Force Military Personnel Center (AFMPC) and received approval for use of the questionnaires at Wright-Patterson. At the suggestion of the base survey control officer, survey control numbers and expiration dates were assigned to each of the questionnaires. The intent was to ensure respondents recognized the surveys had indeed been authorized by AFMPC/MPCYPS. Appropriate copies of the questionnaire packages (both versions) were made and mailed to the random sample of respondents.

In another effort to improve response rate, pre-addressed permit-return envelopes were placed in each of the survey packages. Studies have indicated that providing return envelopes encourages response as a result of simplifying questionnaire return (Emory, 1985; Parten, 1966; Sheard & Gnauck, 1976). Printing the surveys on a laser printer to give a more professional appearance and providing a statement in the sponsor letter guaranteeing anonymity represented other actions taken to induce response. The extent to which any one of these actions actually improved response is uncertain. However, the resultant number of responses acquired for the survey appeared acceptable.

Of 345 surveys mailed, 228 were returned for a response rate of 66 percent. The majority of these were received by the 5 Jul 91 deadline identified in the cover letter for the survey package. Based on the population and stratification of potential respondents (described in *Sample Description*), only about 125 surveys were actually needed to achieve the level of confidence desired in analyzing the data (Ross, 1988; Emory, 1985). As a result, no follow-up letter was sent in an attempt to motivate additional

returns. Also note, no provisions for recipients to substitute respondents in the absence of the addressee existed. While allowing this option may have improved response rate, the potential loss in the representativeness of the sample outweighed the possible benefits. In fact, Dillman suggests, "Substitution does not help; it is only equivalent to building up the size of the initial sample, leaving the bias of nonresponse undiminished" (1978: 47).

Despite the face-value acceptability of the response rate, confidence in the representativeness of the sample depended on an analysis of nonrespondents (Dillman, 1978; Fowler, 1984; Parten, 1966). Using objective data available from *Reports on Individual Personnel* and the source listing of acquisition managers, a matrix of nonrespondents' characteristics was produced to ascertain potential bias and likely impact on data obtained. Table 12 presents the results. In the table, data provided on an individual's educational background is reflected in one of four columns: *Mgt* for management degree, *Eng* for engineering degree, *Both* if the individual possesses both management and engineering degrees, or *Other* representing degrees in general science or other areas not encompassed by management or engineering.

TABLE 12

Characteristics of Nonrespondents

AFSC-->	271X-Intermediate				272X- Junior Managers			
Education Bkgnd Rank	Mgt	Eng	Both	Other	Mgt	Eng	Both	Other
Colonel	3	1	0	3	0	0	0	0
LtColonel	8	6	4	5	0	0	0	0
Major	7	4	2	3	1	1	0	0
Captain	1	1	0	0	11	19	5	5
Lieutenant	0	0	0	0	1	17	0	6

Analyzing the results, no one factor either in terms of rank, AFSC, or educational background characterizes the nonrespondents as a group. Moreover, no remarkable differences existed between the proportion of each of these characteristics in the study sample and those observed in the population. Nonresponse by individuals, therefore, did not indicate presence of bias. (Note, the table does not include data on three [of fifteen total] senior acquisition project managers, AFSC 0029 who did not respond).

This marks conclusion of the discussion on development of the data collection instruments. The following sections are dedicated to describing the study population, study sample, instrument questions, and data analysis methods.

Study Population

The population considered in this study was represented by all military acquisition management personnel within the Aeronautical Systems Division (ASD), the National Aerospace Jet Program (assigned to ASD), and in the 1991 AFIT Graduate Systems Management Program (students) at Wright-Patterson Air Force Base. For the purposes of the study, the term "acquisition manager" represented acquisition personnel across the spectrum of positions, ranks, and experience levels available; any person in a program office (project officers, project managers, program managers, program directors, etc.) involved in daily management of an acquisition project or program. The wide scope of the definition provided a basis for examining the importance of technical competence and any variance thereof throughout the corps of acquisition personnel at various stages of career progression.

Level of sponsorship, time, physical and financial constraints limited the extent of the population which might have been considered. Acquisition managers at Wright-Patterson AFB in Air Force Logistics Command, the Foreign Technology Division, Wright Laboratories, and Human Systems Division offices, in addition to those at other locations, like the Electronics Systems Division and Space Systems Division, may have been included otherwise.

Sample Description

The sample of interest, as described, was drawn from the aforementioned population of acquisition managers located at Wright-Patterson AFB. However, personnel with less than 1 year experience in acquisition were excluded from the sample, considering the expected costs in time and resources to do so outweighed the assumed low utility of the information which could be obtained from these individuals. Incidentally, lack of experience may have made these individuals more indecisive and reluctant to complete the survey. Moreover, as Fowler notes, "if reluctant respondents are induced to answer questions, the poor quality of their reporting may produce more error than their inclusion in the sample avoids" (1984: 60). Omitting the small percentage of "new" acquisition managers from the study was not viewed as biasing the data or affecting the representativeness of the sample. Steps were taken to assure the sample obtained was indeed representative of the total population defined for the study.

2750 Air Base Group MSSQ/MSPD, the Wright-Patterson Air Force Base Personnel Systems Management office, provided a list of all

acquisition managers, individuals with duty Air Force Specialty Codes (AFSC) 27XX or 0029 on base. Based on the records provided, 800 acquisition personnel (from within the Aeronautical Systems Division, the National Aerospace Jet Program (a subunit of ASD), and the AFIT Graduate Systems Management Program) comprised the population defined for this study.

Probability sampling, sampling based on random selection describes the overall method individuals were selected as members of the study sample. Additionally, the sample taken represented a stratified random sample, segregated into mutually exclusive subpopulations using level of acquisition experience (three levels generally associated with Air Force Specialty Codes (AFSC) 272X, 271X, and 0029) as the stratification base.

Stratification was chosen for the benefits it could provide the study. According to Emory, a stratified random sample can "increase a sample's statistical efficiency; provide adequate data for analyzing the various subpopulations; and enable different research methods and procedures to be used in different strata" (1985: 307). More simply, as Parten (1966) portrays, stratified sampling is the most efficient way to insure a sample is representative of a population.

Level of acquisition experience (assumed in relation to Air Force Specialty Code) was chosen as the stratification base because it offered the most potential for maximizing differences among stratum means and minimizing variance of the variables of concern within strata (Emory, 1985: 307).

Proportionate Stratified Random Sample. The source list of acquisition managers provided by the base Personnel Systems Management office

revealed 470 of the 800 total acquisition managers considered were junior managers, Acquisition Project Officers, AFSC 2721 or 2724. Another 315 were identified as the intermediate level Acquisition Management Officers, AFSC 2711 or 2716, and only 15 were listed as the more senior Program Directors, AFSC 0029. Care was therefore taken to assure representative subsamples were acquired among these subpopulations. In other words, each of the subpopulations in the study were represented by samples proportionate to their individual share of the total population. Recognize, however, the group of AFSC 0029s represented an exception. A census of the AFSC 0029s was taken as a result of the overall small number of these individuals. Altogether, proportionate stratified sampling was expected to support greater statistical efficiency than generally would have been possible with a simple random sample (Emory, 1985). Table 13 reveals the results of calculating the sample sizes required for the subpopulations.

TABLE 13

Sample Size Requirements for Proportionate Stratified Random Sampling

Strata (AFSC)	SubPopulation N	Population Relative (part of 800)	Sample Size Required (from formula)	SS Adjusted for Nonresponse, Population Relative
0029	15	.01875	15 (Census)	15 (Census)
271X	315	.39375	56	132
272X	470	.5875	59	197
Total	800		130	345

Based on the study population size, the chosen stratification base, and assuming a response rate of about 38 percent, the desired sample size was

set at 345 to support a confidence level of 90 percent (Krejcie & Morgan, 1970; Ross, 1988).

Values for the sample size required for the strata, Table C, Column 4, were calculated using the formula suggested by Krejcie & Morgan (1970) and Ross (1988):

$$n = \frac{N Z^2(.25)}{[d^2(N - 1)] + [Z^2(.25)]} \tag{1}$$

where, n = sample size needed, N= total subpopulation size, d = precision level (e.g., .10), and Z = a confidence factor associated with d obtained from reference tables. Adding each of the stratum sample sizes computed with the formula resulted in a total required sample size of 130. At this point, however, an assumption was made based on response rates reported for mail surveys (Dillman, 1978; Emory, 1985; Parten, 1966) that only 38 percent of the surveys mailed would be returned. Further, critical and relative to this assumption, it was assumed the expected nonresponse would not characterize any measure of bias. Working backwards then, 345 surveys would be required to assure receipt of at least 130 questionnaires (130 is about 38 percent of 345). Based on a total of 345 surveys, the samples required within each stratum were adjusted (Table C, Column 5) based on the proportion of each relative to the population. For example, since the stratum AFSC 271X represents about 39 percent of the total population of acquisition managers, 132 or almost 39 percent of 345 surveys were mailed to individuals of AFSC 271X. Notably, the approach taken to arrive at the sample sizes involved quite a few judgmental assumptions. It suffices to say, the approach was necessary to ensure an acceptable sampling was

approved by official authorities responsible for monitoring use of surveys in DoD.

After determining the strata sample sizes needed, random number tables (Emory, 1985; Ross, 1988) were used with the source list provided by the base Personnel Systems Management office to randomly select 345 survey respondents from among the three subpopulations of acquisition managers. In the process of selection, date of arrival on station and rank were checked to ensure no acquisition managers with less than 1 year experience were tagged as prospective respondents.

Survey Instrument and Questions

The instruments developed to examine the importance of technical competence, Appendix B, included 11 items designed to provide data applicable to 5 research questions and 19 hypotheses. The variables studied in the examination of technical competency included two individual factors: years of experience in acquisition, and level of technical education; and three situational factors: technical competence (observed) of project team members, level of project technology, and phase of the acquisition process. Review of the literature and studies on project manager skills and competencies (Brown, 1976; Chambers *et al.*, 1970; Einsiedel, 1987; Gadeken, 1986, 1989; Miller, 1987; Posner, 1987; Smith, 1969; Soffron, 1986; Spitz, 1982; Thamhain & Wilemon, 1978; Thornberry, 1987) revealed the importance and requirement for technical competency may be a function of these variables. Additional information motivating selection of each variable is briefly discussed as each survey question is described in order of

the research hypotheses. Table 14 summarizes the relationships among research questions, hypotheses, and survey questions.

TABLE 14

Relationships Among Hypotheses, Survey Questions and Research Questions

#	Hypothesis	Survey Ques #s	Research Question
1	Technical competence is important to acquisition managers	5	1
2	Technical competence is more important to acquisition managers early in their careers	1 and 5	2
3	Relative to other skills, Acquisition managers use their technical competence less as they gain experience	1 and 9	3
4	Acquisition managers with less experience consider technical competence more consequential to project success relative to other skills	1 and 6	3
5	Acquisition managers with less technically qualified project team members consider technical competence more important (than other acquisition managers)	4 and 5	2
6	Relative to other skills, Acquisition managers with better technically qualified project team members use their technical competence less in project activities	4 and 9	3
7	Relative to other skills, Acquisition managers with less technically qualified project team members consider technical competence more consequential to project success	4 and 6	3
8	Acquisition managers in higher technology projects perceive technical competence more important...	2 and 5	2
9	Relative to other skills, Acquisition managers in higher technology projects use their technical competence more...	2 and 9	3
10	Relative to other skills, Acquisition managers in higher technology projects perceive technical competence as more consequential to project success...	2 and 6	3
11	Acquisition managers across all levels of technical education perceive technical competence equally important	3 and 5	3
12	Relative to other skills, Acquisition managers with higher levels of technical education use technical competence more in project activities	3 and 9	3
13	Relative to other skills, Acquisition managers with higher levels of technical education perceive technical competence as more consequential to project success	3 and 6	3
14	Technical competence is more important to acquisition managers in the early phases of the acquisition process	7	2
15	Acquisition managers perceive personal aptitude for seeking and understanding technical information as the more important way to develop technical competency	8	-
16	Relative to others, acquisition managers with less technical education perceive personal aptitude for seeking and understanding technical information more important in developing technical competency	3 an 8	-
17	Acquisition managers perceive technical competence as important to their interpersonal skills	10	2
18	Acquisition managers perceive a variety of skills as equally important to project success	6	-
19	Acquisition managers use each of several skills an equal extent in project activities	9	-

Overall Importance of Technical Competence. The fifth survey question required respondents to indicate the importance of technical competence based on their cumulative experience as an acquisition manager. Available responses represented "ordered categories along a single dimension" providing ordinal level data for analysis (Fowler, 1984: 85). In addition to descriptive evaluation, the data obtained from this question represented the ordered categories constructing part of the contingency tables for the Kruskal-Wallis tests for each of the hypotheses (discussed later) in the study. In particular, responses to survey question 5 applied directly to assessing the first research question and hypothesis 1 (Table 15).

TABLE 15

Hypothesis on the Overall Importance of Technical Competence

Hypothesis	STATEMENT
1	Acquisition Managers perceive Technical Competence is NOT IMPORTANT.

Years of Acquisition Experience. The first survey question asked survey participants to indicate their number of years experience in DoD acquisition, one of the variables in the study. Choices of response for this question indicated a respondent's degree of acquisition experience among three progressively higher levels. The experience "break-points" chosen, 3 years or less, greater than 3 to less than 8, and 8 years or more were established with regard to the certification levels generally outlined in Air Force Regulation 36-27, Acquisition Professional Development (1990).

Years of acquisition experience was chosen as a factor to assess whether technical competence is more important to an acquisition manager in his or her early years, versus later years which may predominantly involve greater levels of overall management responsibility. Some research has shown technical competence is more important to the early success of project managers while other skills, particularly interpersonal skills become more important later on (Rosenbaum, 1990b: 24).

The data obtained from this question identified three different subpopulations. Responses from this question were associated with responses from survey question 5 (ordered categories) forming a contingency table for a Kruskal-Wallis test to support assessment of hypothesis 2 (Table 16). Responses on experience were also used as the basis for forming contingency tables from responses on relative skill rankings, survey questions 6, and 9. The resultant contingency tables supported assessment of hypotheses 2, 3, and 4 using the Kruskal-Wallis test.

TABLE 16

Technical Competence and Experience: Hypotheses 2 thru 4

Hypothesis	STATEMENT
2	TECHNICAL COMPETENCE is MORE IMPORTANT to Acquisition Managers in the EARLY PART of their Careers.
3	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is RELIED UPON LESS by Acquisition Managers as they GAIN EXPERIENCE.
4	Relative to other Attributes and Skills, Acquisition Managers with LESS EXPERIENCE consider TECHNICAL COMPETENCE MORE CONSEQUENTIAL to Project Success.

Projec. Team. The fourth survey question asked respondents to select the best description, one of four ordered categorical responses, to indicate the overall caliber of the technical project team they worked with. The characteristics of project team-members, particularly those responsible for handling technical issues, has been indicated as important to a project manager's effectiveness and to overall project success (Pinto & Slevin, 1989a; Tuman, 1986). Further, some research seems to indicate project managers may not need to be technically competent if they have adequate technically qualified individuals among their project team (Carter, 1988; Hower & Orth, 1963; Thamhain, 1989). This question was included in the survey to assess if the importance of technical competence varies as a function of the technical capability possessed by project team members.

Responses on the caliber of technical project teams were aligned with responses on the perceived importance of technical competence to form a contingency table for a Kruskal-Wallis test assessing hypothesis 5 (Table 17). Responses project teams were also used with responses on relative skill rankings, questions 6 and 9, to assess hypotheses 6 and 7 (Table 17).

TABLE 17

Technical Competence & Project Teams: Hypotheses 5 thru 7

Hypothesis	STATEMENT
5	TECHNICAL COMPETENCE is MORE IMPORTANT to Acquisition Managers with LESS TECHNICALLY-QUALIFIED Project Team Members.
6	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is relied upon LESS by Acquisition Managers with MORE Technically Competent Project Team Members.
7	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is viewed MORE CONSEQUENTIAL to project success by Acquisition Managers with LESS Technically-Qualified Project Teams.

Project Technology. The second survey question asked respondents to select one of three ordered categorical responses provided, to indicate the type of technology characterizing their current project. Studies have indicated the need for more technically competent individuals to manage higher technology projects (Cohen, 1986; Hoffman, 1989; Thornberry & Weintraub, 1983). As a result, this question was included to assess whether the importance of technical competence varied as a function of the technology involved in a project.

Responses from question 2 describing project technology level were used with responses on the perceived importance of technical competence to form a contingency table for a Kruskal-Wallis test assessing hypothesis 8 (Table 18). Responses from survey question 2 were also used with responses on relative skill rankings, questions 6 and 9, to support analysis of hypotheses 9 and 10 (Table 18).

TABLE 18

Technical Competence & Project Technology: Hypotheses 8 thru 10

Hypothesis	STATEMENT
8	TECHNICAL COMPETENCE is MORE IMPORTANT to Acquisition Managers in HIGHER TECHNOLOGY Projects.
9	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is relied upon MORE by Acquisition Managers involved in HIGHER TECHNOLOGY Projects.
10	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is viewed MORE CONSEQUENTIAL to project success by Acquisition Managers in HIGHER TECHNOLOGY Projects.

Technical Education. Survey question 3 required respondents to choose one of five ordered categories provided, to describe the number of credit hours in graduate and undergraduate technical subjects they had completed which contributed to their technical competency. Many studies on acquisition managers have revealed technical education as a common attribute (Chambers *et al.*, 1970; Dwyer, 1990; Miller 1987) and several others have indicated many project managers have backgrounds as engineers (Smith, 1969; Brown, 1976). On the other hand, records show that not all acquisition managers have a technical educational background (Sanford, 1991; Miller, 1991). The focus of this particular question was to evaluate whether the importance of technical competence varied with level of technical education.

Data from question 3 on technical education level were used with responses on the perceived importance of *technical competence* to form a contingency table for a Kruskal-Wallis test assessing hypothesis 11. Responses on technical education were also used with responses on relative skill rankings, questions 6 and 9, to assess hypotheses 12 and 13 (Table 19).

TABLE 19

Technical Competence & Technical Education: Hypotheses 11 thru 13

Hypothesis	STATEMENT
11	TECHNICAL COMPETENCE is EQUALLY IMPORTANT to Acquisition Managers of ALL Technical Education Levels.
12	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is relied upon MORE by Acquisition Managers with HIGHER levels of Engineering Education.
13	Relative to other Attributes and Skills, TECHNICAL COMPETENCE is viewed MORE CONSEQUENTIAL to Project Success by Acquisition Managers with HIGHER levels of Technical Education.

Acquisition Phase of Project. The seventh question of the survey asked acquisition managers to rank the phases of the acquisition process in the order which reflected when it was most important to have technical competence. Several studies have concluded that technical problems are more prevalent during certain stages of the acquisition process/project lifecycle (Archibald, 1976; Pinto & Slevin, 1988b, 1989a; Posner, 1986, Spitz, 1982). Accordingly, this question was included to assess whether the importance of technical competence varied as a function of the phase of the acquisition process.

Responses on acquisition phase were used in a Friedman's test to assess hypothesis 14 (Table 20).

TABLE 20

Technical Competence & Acquisition Phase: Hypothesis 14

Hypothesis	STATEMENT
14	TECHNICAL COMPETENCE is MORE IMPORTANT to Acquisition Managers during the EARLY PHASES of the Acquisition Process.

Developing Technical Competence. Survey question 8 required respondents to rank order 7 items to indicate their relative importance in developing technical competency. In other words, the question was designed to evaluate what acquisition managers believed helped them develop technical competence. With the current focus and efforts to improve the acquisition workforce (Fox, 1990; Wade, 1986), this issue seemed very relevant. The choices provided as responses were based on a variety of studies which addressed education, training or selection of

acquisition managers (Rubin et at., 1967; Bennett & McMullan, 1987; Babcock, 1974; Thornberry & Weintraub, 1983).

Responses from methods of developing technical competence were analyzed using Friedman's test statistic to determine if any evidence existed that any one or a number of the development mechanisms among those offered contributed more to development of technical competence. The same data were also used in a Kruskal-Wallis test with data from survey question 1. Results from both were applied to analysis of hypotheses 15 and 16 (Table 21), respectively.

TABLE 21

Developing Technical Competence: Hypotheses 15 and 16

Hypothesis	STATEMENT
15	Acquisition Managers rely PRIMARILY upon PERSONAL APTITUDE to develop TECHNICAL COMPETENCE.
16	Acquisition Managers with LESS Technical Education rely MORE on their PERSONAL APTITUDE to develop TECHNICAL COMPETENCE.

Ranking of Attributes. Survey question 9 required respondents to rank order several attributes/skills, including technical competency based on the amount of time the acquisition managers relied on each to perform their jobs. Survey question 6 used the same list of attributes/skills, but required respondents to rank order the items based on the relative impact of each on project success. Some studies have concluded technical competence is not one of the more important attributes relative to others (Gadeken, 1989b; Posner, 1987), but this appears to have been found primarily in terms of the amount of time spent using a particular attribute. At the same time, other

studies have found the more consequential problems in a project are technical (Defense Manufacturing Management, 1989). Questions 6 and 9 were intended to examine these issues with regard to the importance of technical competence.

As previously indicated, responses from questions 6 and 9, skill rankings, were applied with responses from survey questions 1 thru 4 to form contingency tables for Kruskal-Wallis tests and analysis of hypotheses 3, 4, 6, 7, 9, 10, 12, and 13. Additionally, Friedman's test was applied to individual data from questions 6 and 9 to examine the importance acquisition managers placed on various skills. Hypotheses for these tests, 18 and 19, respectively, are presented in Chapter IV. Table 22 shows the skills respondents ranked in questions 6 and 9.

TABLE 22

Skills Respondents Ranked in Survey Questions 6 and 9

SKILL	Description
Organizational skills	planning, goal-setting, analyzing, etc.
Abilities in communication	listening, persuading, etc.
Technical competence	ability to apply technical experience and knowledge, etc
Coping skills	patience, persistence, flexibility
Leadership	influencing others, providing direction, vision, etc.
Team building skills	fostering commitment, coaching

Impact of Technical Competence on Interpersonal Capabilities. Question 10 was designed to evaluate how technical competence contributed to an acquisition manager's interpersonal skills. Many research efforts have indicated technical competence contributes to a project manager's credibility, influence, and capacity to deal with human relations problems

(Cleland, 1988; Pitts, 1990; Posner, 1987; Thamhain, 1989). Question 10 focused on examining this issue.

In particular, data from question 10 reflecting the perceived importance of technical competence to interpersonal skills were descriptively evaluated to support analysis of hypothesis 17 (Table 23).

TABLE 23

Technical Competence and Interpersonal Skills: Hypothesis 17

Hypothesis	STATEMENT
17	Acquisition Managers consider TECHNICAL COMPETENCE important to their INTERPERSONAL SKILLS.

An open-ended question, number 11, was provided to allow respondents the opportunity to provide comments (Emory, 1985). The intent was to acquire information and opinions with regard to the content of survey questions and any explanations respondents may have been willing to offer on the responses they gave. As Fowler (1984) suggests, respondents like the chance to express some views in their own words.

Analysis Method

EXCEL 3.0, a spreadsheet package, and two statistical analysis packages, STATVIEW+, and SYSTAT, were used to perform analysis of the survey results using an Apple Macintosh small computer. Analysis of the hypotheses involved several different statistical test methods: the Kruskal-Wallis, the Friedman test, use of rank-order correlation coefficients, and a full range of descriptive statistical calculations.

The preponderance of data analysis employed the Kruskal-Wallis and the Friedman tests. These tests were selected based on several considerations:

- the power of available statistical tests
- the level of measurement achieved in the study
- applicability of statistical models to the research data

According to Siegel, the most powerful tests are those which have the strongest or most extensive assumptions (1956:19). By definition, then, parametric tests, techniques based on several assumptions about the values, or parameters characterizing the nature of a population from which observations are drawn (Siegel, 1956), are generally the more powerful. In fact, Siegel indicates if data can be appropriately analyzed using a parametric test, no other test will be more powerful in rejecting the null hypothesis when the null is false (1956:19). However, it is also possible to use a non-parametric test, avoiding some of the assumptions of the parametric tests, and retain the same power-efficiency by increasing the sample size a proper amount (Siegel, 1956). All other things being equal then, in terms of power-efficiency perhaps nonparametric tests yield but little preference to parametric tests.

In this study, though, not all the assumptions required of applicable parametric tests could be met. Parametric tests require values representing at least interval scale (Conover, 1980; Siegel, 1956). Data collected in this research represented rank-order or ordinal level measures. Additionally, few of the assumptions necessary for parametric tests could be made about the nature of the populations from which the

study data were collected. As a result, nonparametric tests were chosen to analyze the hypotheses for this study.

Several nonparametric tests exist (Conover, 1980; Neter, Wasserman, & Kutner, 1990; Siegel, 1956). Choice of which tests to use basically involved selecting the techniques most appropriate for the analyses required. A number of the hypotheses in this study required a determination of whether differences among several independent groups were a reflection of differences in populations; whether the samples came from the same population or not. Other hypotheses required a comparison and assessment of whether an overall difference existed among several conditions before isolating out any pair of conditions in order to test the significance of the difference between them. The Kruskal-Wallis and Friedman tests, respectively, applied to these analysis conditions (Conover, 1980; Neter *et al.*, 1990; Siegel, 1956).

In particular, both tests are based on rank-order and provide information about the relative magnitudes of the underlying variables (Conover, 1980; Kerlinger, 1973; Neter *et al.*, 1990; Siegel, 1956). Further, for tests of several independent groups, the Kruskal-Wallis is the most powerful of the nonparametric tests. Compared with the most powerful parametric test, the F test, it has power efficiency of 95.5 per cent (Conover, 1980; Siegel, 1956). In empirical studies, the Friedman test has revealed an efficiency comparable to the F-test as well (Siegel, 1956). Additionally, computations for both the Kruskal-Wallis and Friedman tests are neither complicated, nor extensive (Conover, 1980; Siegel, 1956)... an advantage considering the number of hypothesis tests to perform in this study.

Even though StatView + and SYSTAT capably performed the required tests for this study, a spreadsheet template was constructed to conduct the Kruskal-Wallis and any required multiple comparisons for both the Kruskal-Wallis and Friedman tests. Design of the template mirrored methods suggested by Conover (1980). For the Kruskal-Wallis, the approach centered on use of a contingency table format, "where the rows represent ordered categories and the columns represent (the) different populations" (Conover, 1980: 233).

Consider the following illustration where the null hypothesis H_0 is defined as: Acquisition managers among all three levels of experience consider technical competence equally important, and the alternate is H_a: Acquisition managers with different levels of experience do not value the importance of technical competence the same.

The rows in the model contingency table (Figure 7) would be represented by the 5 ordered categorical responses to question 1 in the survey. The columns in the model table would be represented by the three different subpopulations of acquisition managers defined by the responses on experience available for question 2 (i.e., less than 3 years, >3 to < 8, and 8 years or more). Note, the model contingency table illustrates the general case, where k populations and c columns may exist.

In the table, O_{ij} is the number of observations in population j that fall into the ith category (Conover, 1980). In the scenario given, O_{11} would represent the number of times acquisition managers with less than 3 years experience indicated technical competence was absolutely essential. Similarly, O_{21} would represent the number of times acquisition managers

with less than 3 years experience indicated technical competence was extremely important... and so on.

Population	1	2	3	...	k	Row Totals	Average Rank, $\bar{R}_i$
Category 1	O_{11}	O_{12}	O_{13}	...	O_{1k}	t_1	$(t_1+1)/2$
Category 2	O_{21}	O_{22}	O_{23}	...	O_{2k}	t_2	$t_1+(t_2+1)/2$
Category 3	O_{31}	O_{32}	O_{33}	...	O_{3k}	t_3	$t_1+t_2+(t_3+1)/2$
...	...	...	...	...			
c	O_{c1}	O_{c2}	O_{c3}	...	O_{ck}	t_c	$\sum_{i=1}^{c-1} t_i+(t_c+1)/2$
Column Totals	n_1	n_2	n_3	...	n_k	N= Grand Total	

Figure 7. Contingency Table for Kruskal-Wallis Test: General Case (Source: Conover, 1980: 233)

After the values for the observations are properly placed in the table, the rows and columns are totaled. Each row total is then used to calculate an average rank, $R_i$bar, with the formulas shown. The sum of the ranks in each population (column), R_j is then computed, along with the sample variance, S^2. The values for R_j and S^2 are obtained from the following formulas:

$$R_j=\sum_{i=1}^{c} O_{ij}\bar{R}_i \tag{2}$$

$$S^2=\frac{1}{N-1}\left(\sum_{i=1}^{c} t_i\bar{R}_i^2-N(N+1)^2/4\right) \tag{3}$$

These are subsequently substituted into the following equation to compute a value of the test statistic T and establish acceptance or rejection of the null hypothesis.

$$T = \frac{1}{S^2}\left(\sum_{i=1}^{k}\frac{R_i^2}{n_i} - \frac{N(N+1)^2}{4}\right) \tag{4}$$

The null is rejected at the level alpha if T exceeds the *1- alpha* quantile obtained (Conover, 1980: 231). Tables are commonly referenced to make the determination. If the null is rejected, a multiple comparisons procedure is used to determine which pairs of populations (columns) tend to differ (Conover, 1980). The procedure essentially represents the parametric procedure called Fisher's least significant difference, except that computations are performed on the ranks rather than the data (Conover, 1980: 236).

Multiple Comparison for the Kruskal-Wallis. In the event the null is rejected, populations i and j can be concluded different if the following inequality is satisfied in performing a multiple comparison (Conover, 1980):

$$\left|\frac{R_i}{n_i} - \frac{R_j}{n_j}\right| > t_{1-(\alpha/2)}\left(S^2\frac{N-1-T}{N-k}\right)^{\frac{1}{2}}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)^{\frac{1}{2}} \tag{5}$$

Multiple Comparison for the Friedman Test. As mentioned heretofore, the Friedman test was used in testing several hypotheses.

Summarizing again, perhaps providing more perspective, the Freidman test statistic measures the degree of difference between the rank averages and their expected values (Devore, 1987). As with the Kruskal-Wallis test, Friedman's test rejects H_0 when the computed value of the test statistic is too large (Devore, 1987: 624). The null hypothesis in general terms states no difference exists among treatment effects. When the null is true, the rank averages computed for treatments are close in value (Devore, 1987: 624). If the null is rejected signifying treatments do not have identical effects, a multiple comparison is performed similar to that for the Kruskal-Wallis. The objective in such cases is to determine which treatments can be considered different. In performing the multiple comparison for the Friedman test, treatments *i* and *j* are considered different if the following inequality is satisfied (Conover, 1980: 300):

$$|R_j - R_i| > t_{1 - alpha/2} \left[\frac{2b(A_2 - B_2)}{(b-1)(k-1)} \right]^{1/2} \tag{6}$$

where R_i and R_j are the rank sums for treatments *i* and *j*, *b* is the number of blocks in the block design for the test, *k* is the number of total treatments and

$$A_2 = \frac{bk(k+1)(2k+1)}{6} \tag{7}$$

$$B_2 = 1/b \sum_{j=1}^{k} R_j^2 \tag{8}$$

Research Assumptions

This study was accomplished based on several assumptions. To begin with the mail survey was assumed to offer an appropriate and cost-effective means of collecting data for this research. In addition, the source listing of acquisition managers provided by the WPAFB Personnel Systems Management office was assumed to be accurate, and the sample drawn from the population defined by the list was assumed to be representative. If the source list had not been reasonably accurate, all the members of the population *acquisition managers* would not have had an equal opportunity for inclusion in the sample (Dillman, 1978; Parten, 1966).

Also, the terms, instructions, questions, and other statements included in the survey instruments were assumed to be appropriate, equally understandable, and meaningful to respondents. Further, the data collection instruments were assumed to have produced meaningful, valid data applicable to the research; the data accurately reflected respondents' experience and perceptions and corresponded directly to the research objectives. Last, no errors were assumed made in the process of transposing and tabulating data from the questionnaires. Several checks were made nonetheless.

IV. Results

Introduction

This chapter presents the results obtained from applying the methodology described in Chapter III. Observations, descriptive data, and statistical results are reported in addressing each of the hypotheses proposed by this study. The analysis of results focuses on revealing as much information as possible with regard to the perceived importance of technical competence, and how certain individual and situational factors may influence perceptions. Review of the results begins with descriptive statistics on the study sample, then follows with a sequential review of findings obtained in testing each of the study hypotheses. The data collection instruments and the data obtained from the instruments are provided for reference at Appendix B and Appendix C, respectively. Discussion of significant findings and associated implications follows in Chapter V.

Sample Description

The 2750 Air Base Group MSSQ/MSPD, Personnel Systems Management Branch, provided a source list of all the acquisition managers assigned to Wright-Patterson Air Force Base. The list identified 800 acquisition managers, 470 of AFSC 272X, 315 of AFSC 271X, and 15 program directors, AFSC 0029. Proportionate random samples were drawn for each of these subpopulations to ensure an overall representative sample for the study. Based on a goal of achieving a .10 confidence level, 345 surveys were distributed; 197 to acquisition managers in AFSC 272X, 132 to acquisition managers in AFSC 271X, and one to each of the 15

managers of AFSC 0029 (a census of this group). Figure 8 depicts the relationships by AFSC between the number of available acquisition managers, the number surveyed, and the number within each AFSC responding to the survey. Of the 345 surveys mailed, 228 useable surveys (115 version 1, 113 version 2) were returned for a response rate of 66.1 percent. Another one percent were returned, but not completed due to recent relocation of personnel to other duty stations. Of the 228 surveys, less than 2 percent had a question where a response had been overlooked or intentionally left unanswered. In most cases, comments were provided by respondents if a question was left unanswered. In any case, blanks in the data (Appendix C) reflect those cases where data were not provided or not given in the format outlined in instructions.

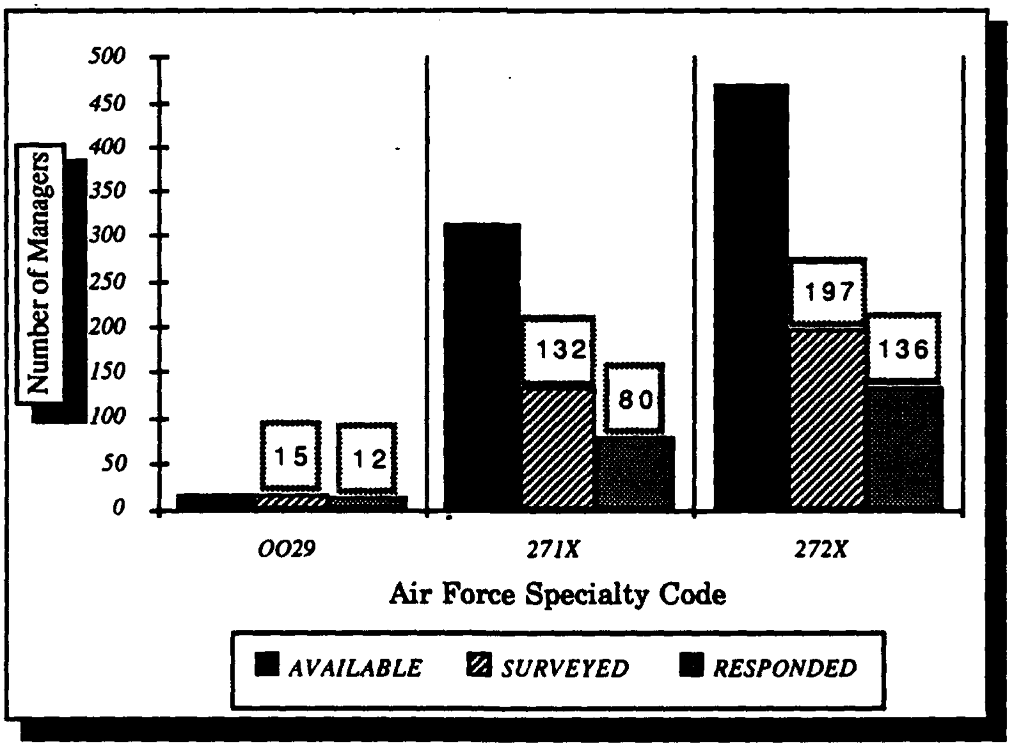


Figure 8. Acquisition Managers Survey Participation

Although Figure 8 seems to imply only a small number of senior acquisition managers work at Wright-Patterson AFB, looking at the data in terms of experience level provides a somewhat different picture. Figure 9 shows the distribution of respondents by experience level, one of the demographic factors in the study. As this chart reveals, even though just a few managers serve in senior leadership (AFSC 0029) positions, a large portion of the acquisition manager population is represented by officers with 8 or more years of experience. Many of these individuals, though not assigned to key leadership positions, are comparable in rank to the officers filling AFSC 0029 billets. Figure 8 also reflects (in terms of respondents) the smaller percentage of the acquisition manager population represented by individuals relatively new to the acquisition field. Recognize although generally the case, acquisition experience is not necessarily an accurate reflection of rank. Some of the most senior managers also have very few years acquisition experience.

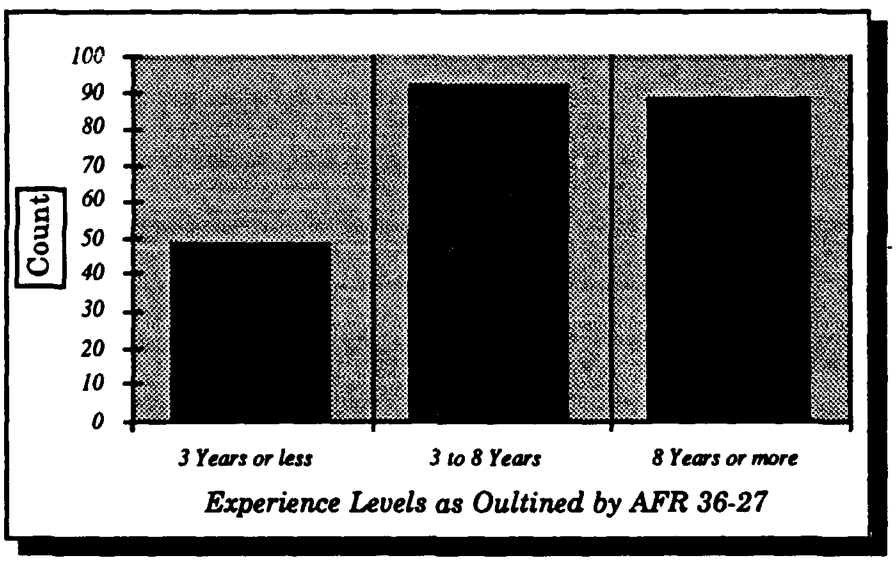


Figure 9. Respondents by Acquisition Experience Level

Hypotheses, Tests and Associated Findings

The following discussion presents the results related to the statistical analyses and tests performed to investigate the research questions and allied hypotheses. Each hypothesis is discussed individually, primarily with focus on reporting significant statistical results. Additional information on hypotheses is compiled in Appendix D, which provides descriptions of the null and alternate hypothesis statements, frequency distributions (as applicable), and detailed statistical results obtained for each hypothesis test. Table 24 provides a summary of the analyses /tests conducted on each of the study hypotheses.

Hypothesis #1. What is the perceived importance of technical competence to acquisition managers? This embodies the first research question in entirety, as well as the first hypothesis.

Question 5 on the two data collection instruments was designed to reliably, objectively, and accurately measure the perceived importance of technical competence to acquisition managers using an ordinal response structure. Figure 10 describes the relative frequency distribution, the frequency of each of the ordinal responses as a percentage of the total number of responses obtained. The graph indicates a majority of acquisition managers appear to perceive technical competence to be extremely important or absolutely essential, "frequently making the difference in their ability to manage." Of the 228 respondents, 100 or 43.86 percent, chose the response describing technical competence as "extremely important." This was the most frequently observed response.

The median response of the five possible options for question 5 also proved to be response 2, "extremely important."

TABLE 24

Overview of Hypotheses and Associated Statistical Tests

#	Hypothesis	Survey Ques #s	Statistics
1	Technical competence is important to acquisition managers	5	Descriptive, %'s, Frequency Distribution
2	Technical competence is more important to acquisition managers early in their careers	1 and 5	Kruskal-Wallis
3	Relative to other skills, Acquisition managers use their technical competence less as they gain experience	1 and 9	Kruskal-Wallis
4	Acquisition managers with less experience consider technical competence more consequential to project success relative to other skills	1 and 6	Kruskal-Wallis
5	Acquisition managers with less technically qualified project team members consider technical competence more important (than other acquisition managers)	4 and 5	Kruskal-Wallis
6	Relative to other skills, Acquisition managers with better technically qualified project team members use their technical competence less in project activities	4 and 9	Kruskal-Wallis
7	Relative to other personal attributes and skills, Acquisition managers with less technically qualified project team members consider technical competence more consequential to project success	4 and 6	Kruskal-Wallis
8	Acquisition managers in higher technology projects perceive technical competence more important...	2 and 5	Kruskal-Wallis
9	Relative to other skills, Acquisition managers in higher technology projects use their technical competence more...	2 and 9	Kruskal-Wallis
10	Relative to other skills, Acquisition managers in higher technology projects perceive technical competence as more consequential to project success...	2 and 6	Kruskal-Wallis
11	Acquisition managers across all levels of technical education perceive technical competence equally important	3 and 5	Kruskal-Wallis
12	Relative to other skills, Acquisition managers with higher levels of technical education use technical competence more in project activities	3 and 9	Kruskal-Wallis
13	Relative to other skills, Acquisition managers with higher levels of technical education perceive technical competence as more consequential to project success	3 and 6	Kruskal-Wallis
14	Technical competence is more important to acquisition managers in the early phases of the acquisition process	7	Friedman's
15	Acquisition managers perceive personal aptitude for seeking and understanding technical information as the more important way to develop technical competency	8	Friedman's
16	Relative to others, acquisition managers with less technical education perceive personal aptitude for seeking and understanding technical information more important in developing technical competency	3 an 8	Kruskal-Wallis
17	Acquisition managers perceive technical competence as important to their interpersonal skills	10	Descriptive, Percentages, Freq. Distribution
18	Acquisition managers perceive a variety of skills as equally important to project success	6	Friedman's
19	Acquisition managers use each of several skills an equal extent in project activities	9	Friedman's

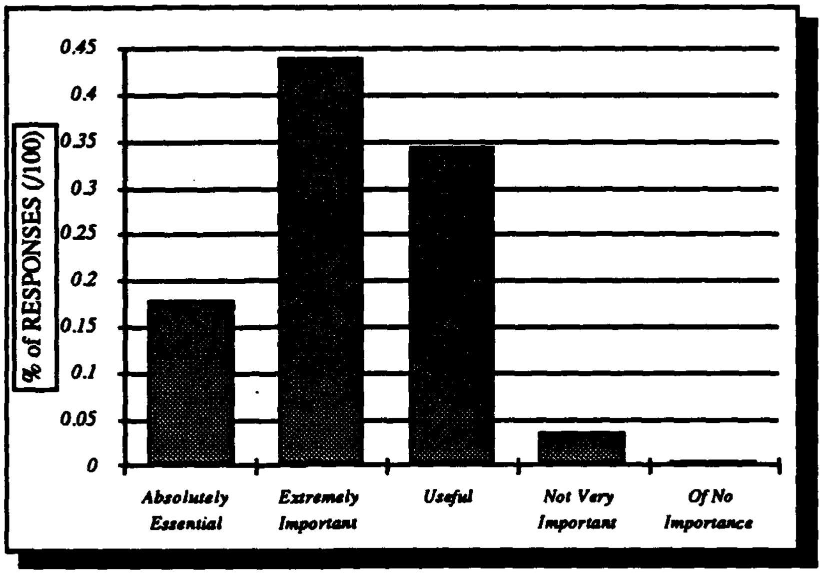


Figure 10. Perceived Importance of Technical Competence: Relative Frequency Distribution

Hypothesis #2. Technical competence is more important to acquisition managers early in their careers (as measured in terms of acquisition experience).

A Kruskal-Wallis test was performed to assess if the population distribution functions for different experience levels were identical. Based on a p-value of .92, the test indicated the three populations of acquisition managers (grouped by experience) perceived the importance of technical competence similarly.

A graph (Figure 11) depicting the relative frequency distributions of the three "experience" populations of acquisition managers illustrates the results obtained with the Kruskal-Wallis test. Appendix D provides specifics on the test results.

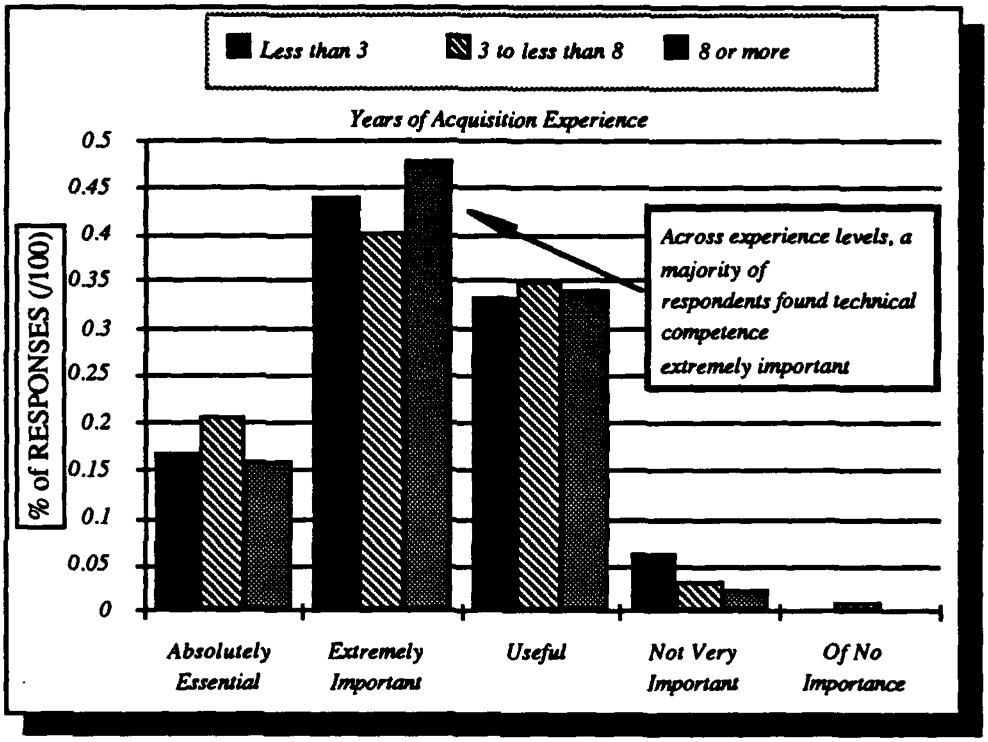


Figure 11. Perceived Importance of Technical Competence as a Function of Acquisition Experience Level: Relative Frequencies.

The distributions suggest a majority of acquisition managers from all experience levels in this study perceived technical competence as *extremely important* or *absolutely essential*..

Hypothesis #3. Relative to other skills, Acquisition managers use their technical competence less as they gain experience.

A Kruskal-Wallis test was performed to evaluate Hypothesis #3. The test sought to determine if the population distribution functions for different experience levels were identical in terms of the perceived importance of technical competence relative to other skills, as a function of time dedicated to each skill in project activities.

The results of the test (p = .1775), detailed in Appendix D, supported acceptance of the null hypothesis.

Hypothesis #4: Acquisition managers with less experience perceive technical competence more consequential to project success relative to other skills.

The Kruskal-Wallis test of this hypothesis revealed the three populations of acquisition managers (grouped by experience) are essentially equal in the perceived importance of technical competence to project success, relative to other skills.

Hypothesis #5. Acquisition managers with less technically qualified project team members consider technical competence more important (than other acquisition managers).

The Kruskal-Wallis for this hypothesis produced a p-value of .0012, rejecting the null hypothesis and implying acquisition managers grouped relative to technical project team capabilities differed in the perceived importance of technical competence.

Figure 12, the relative frequency of responses for each grouping of acquisition managers, supports the finding. Note, only three of four possible groups were represented by responses obtained in the sample. No subjects rated their technical project team members *Poor*. While this may indicate some degree of lenient tendency, the extent of such would seem unlikely considering the sample size obtained. One possible explanation would be an assumption that DoD acquisition projects require very capable and qualified personnel available. Therefore, few if any cases of *Poor* project team members would be observed.

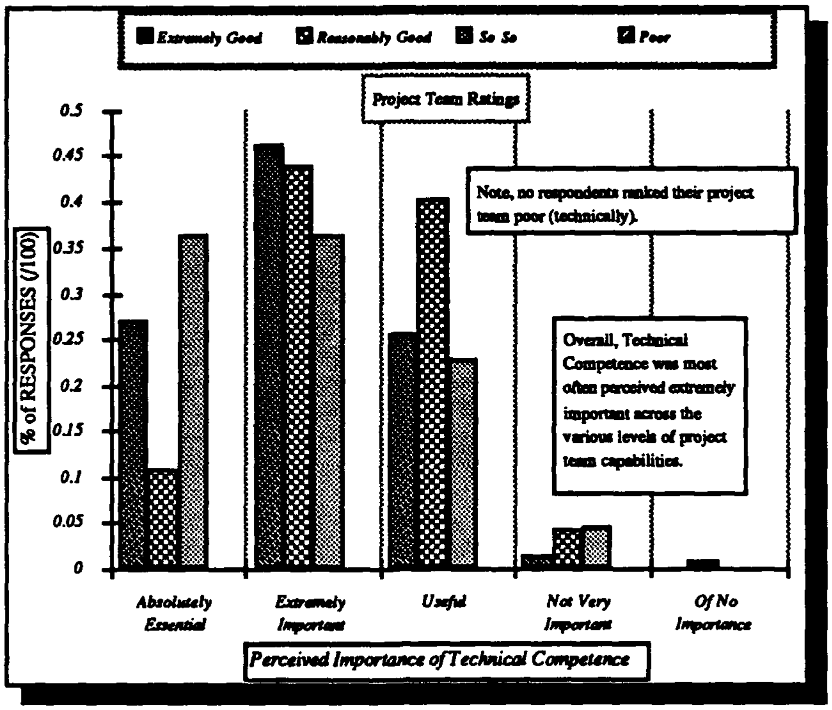


Figure 12. Perceived Importance of Technical Competence as a Function of Technical Project Team Capabilities: Relative Frequencies.

In any case, the rejection of the null called for a multiple comparison to determine which pairs of groups differed significantly. At a level of significance of .05, the comparison revealed acquisition managers with Reasonably Good technical project team members perceive technical competence significantly less important than those with either Extremely Good or So-So technical team members. In other words, technical competence is perceived to be more important to acquisition managers with extremely good teams or mediocre teams, than it is to managers of reasonably good teams. Appendix E provides actual values obtained in the multiple comparison for reference.

Hypothesis #6. Relative to other skills, acquisition managers with better technically qualified project team members use their technical competence less in project activities.

The test disclosed a somewhat low p-value ($p = .106$), and the null could not be rejected at a significance level of .05. Based on the test, the three populations of acquisition managers represented are essentially the same in perceived importance of technical competence relative to extent of use among other skills in project activities.

Hypothesis #7. Relative to other skills, Acquisition managers with less technically qualified project team members consider technical competence more consequential to project success.

In Hypothesis #7, the Kruskal-Wallis test inspected whether acquisition managers of project teams with different technical expertise levels were equal in the perceived importance of technical competence to project success relative to other skills.

At a significance level of .05, the test produced a p-value of .169 resulting in acceptance of the null hypothesis. According to the Kruskal-Wallis test, the three groups of acquisition managers represented are essentially the same in average perceived importance of technical competence to project success relative to other skills.

Hypothesis #8. Acquisition managers in higher technology projects perceive technical competence more important.

The Kruskal-Wallis produced a p-value equal to .156), resulting in acceptance of null at a significance level of .05. Accordingly, the three groups of acquisition managers organized by level of project technology are

virtually the same in average perceived importance of technical competence.

Hypothesis #9. Relative to other skills, acquisition managers in higher technology projects use their technical competence more than those in less technical projects.

The test revealed a p-value of .61, supporting acceptance of the null hypothesis (Appendix D). As a result, the three groups of acquisition managers categorized by level of project technology may be construed to hold similar views regarding the importance of technical competence relative to other skills, based on extent of use in project activities. Figure 13 depicts the relative frequency of responses for each of the response groups, which generally appear to support this conclusion.

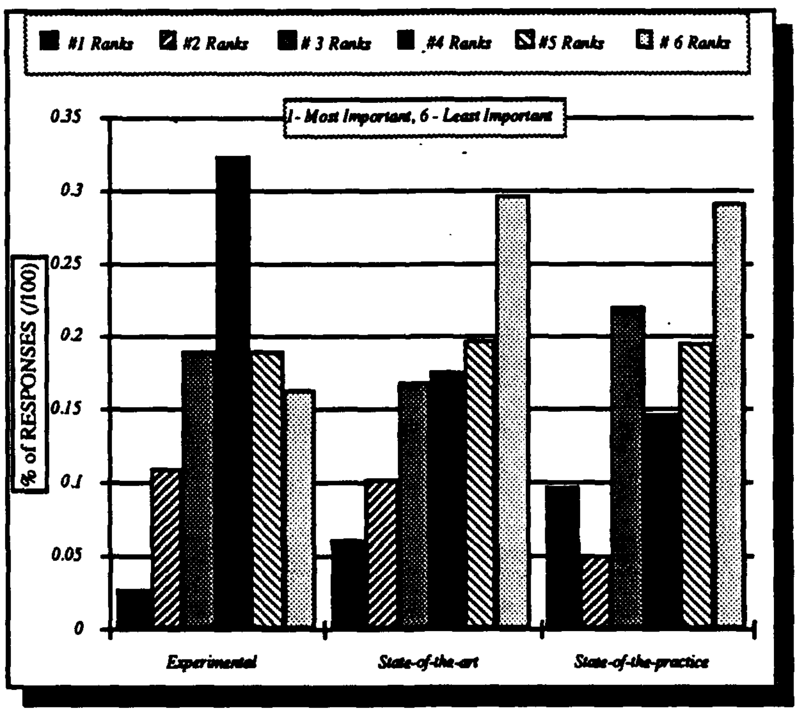


Figure 13. Rankings of Technical Competence Relative to Use Among Other Skills in Project Activities, as a Function of Project Technology Level: Relative Frequencies.

Hypothesis #10. Relative to other skills, acquisition managers in higher technology projects perceive technical competence as more consequential to project success than those acquisition managers in less technical projects.

The Kruskal-Wallis test revealed a p-value of .90. The null hypothesis was therefore accepted. Considering the statistical results, the three populations of acquisition managers in this hypothesis may be considered identical in their perceptions about the importance of technical competence to project success relative to other skills. The relative frequency of responses depicted in Figure 14 for each of the groups, appears to promote this same conclusion.

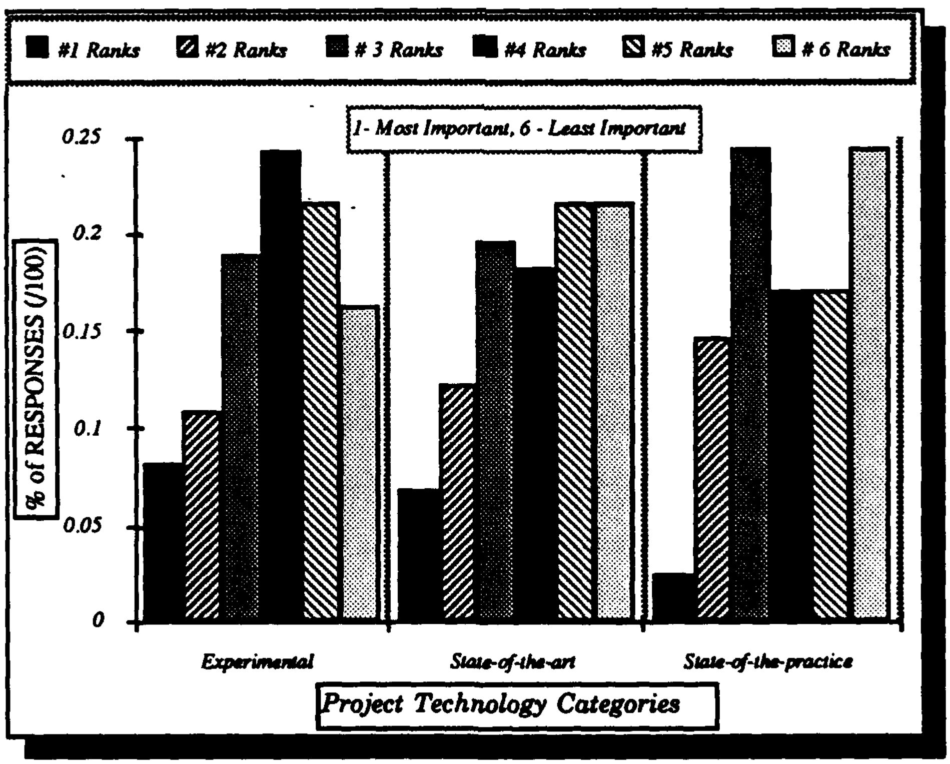


Figure 14. Perceived Importance of Technical Competence to Project Success Relative to Other Skills, as a Function of Project Technology Level: Relative Frequencies.

Hypothesis #11. Acquisition managers across different levels of technical education perceive technical competence equally important.

At a significance level of .05, the test results disclosed a p-value of .01 supporting rejection of the null hypothesis. The five response groups of acquisition managers considered in this hypothesis differed in perceived importance of technical competence. Figure 15 reveals the relative frequency distributions for the responses which supports the results. Of course, a multiple pairwise comparison of the five populations representing progressive levels of technical education was needed to assess significant differences between each.

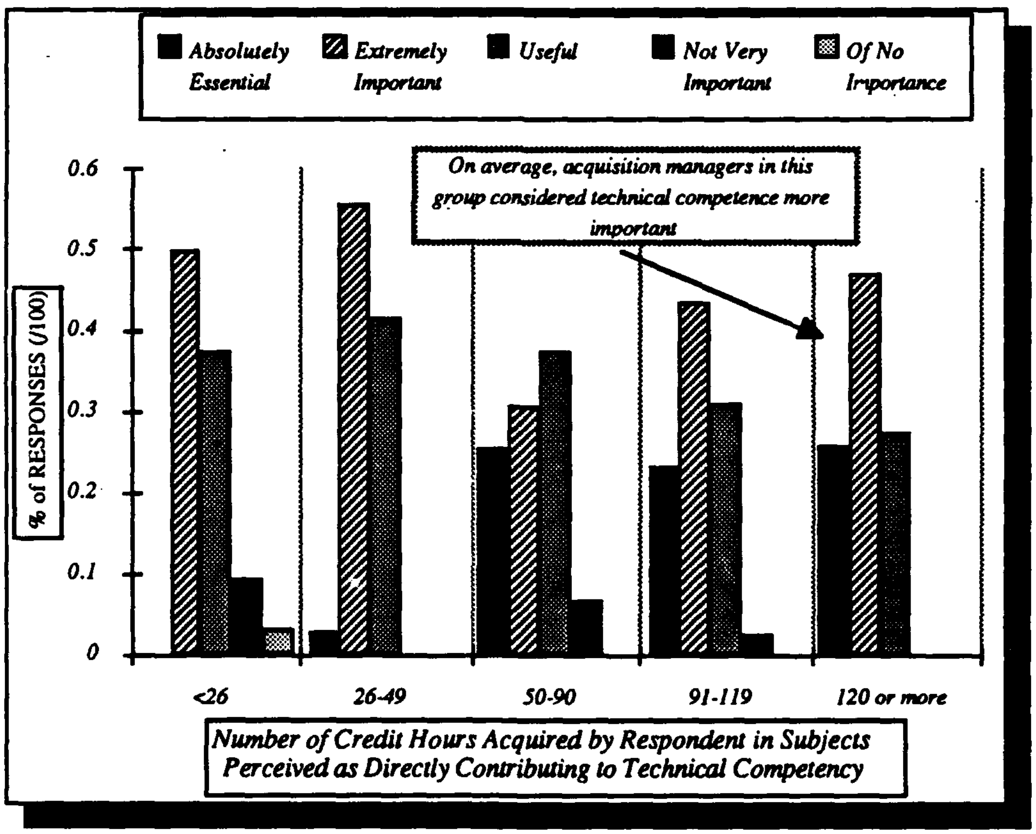


Figure 15. Perceived Importance of Technical Competence as a Function of Level of Technical Academic Training: Relative Frequencies.

The comparison results, Appendix E, indicated acquisition managers with 91 or more credit hours in technical academic training perceive technical competence significantly more important than those with 26 hours or less. Also, those with 26 to 49 credit hours in technical education were found to perceive technical competence significantly less important in comparison to acquisition managers with 120 or more credit hours. Overall, the test results support the conclusion that acquisition managers with the most technical academic training perceive technical competence more important than acquisition managers with significantly less technical education.

Hypothesis #12. Relative to other skills, acquisition managers with higher levels of technical education use technical competence more in project activities compared to acquisition managers with less technical academic training.

Hypothesis #13. Relative to other skills, acquisition managers with higher levels of technical education perceive technical competence as more consequential to project success in comparison to acquisition managers with less technical academic training.

In testing Hypotheses #12 and 13, the Kruskal-Wallis demonstrated whether the groups of acquisition managers among different levels of technical academic training were the same in perceived importance of technical competence:

- ...relative to other skills, based on extent of use in project activities
- ...to project success relative to other skills.

In both cases, the test results failed to reject the null at a .05 level of significance (Appendix D). Differences in technical academic training did

not influence perceptions of the importance of technical competence relative to other skills in the scope of Hypotheses 12 and 13.

Hypothesis #14. Technical competence is more important to acquisition managers in the early phases of the acquisition process.

Friedman's two-way analysis of variance, an extension of the sign test (Conover, 1980) was performed to test treatment effects. That is, the Friedman test was used to determine existence of treatment differences and whether rank totals for each of the acquisition phases differed significantly enough to indicate the perceived importance of technical competence varied as a function of project phase.

The results of the Friedman two-way analysis of variance, Appendix D justified rejection of the null hypothesis at a .05 level of significance. The p-value obtained was .0001. In support, Figure 16 reveals the mean ranks.

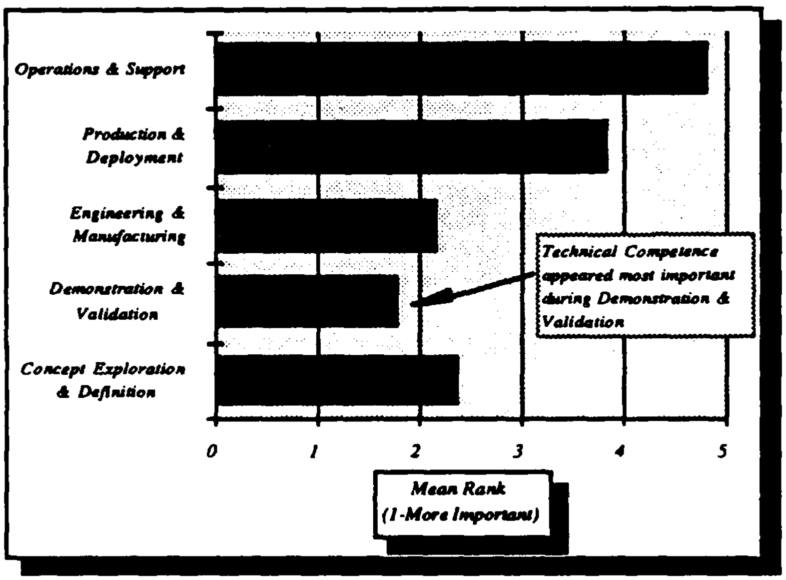


Figure 16. Mean Rankings of Acquisition Phases Relative to the Perceived Importance of Technical Competence within each Phase: Relative Frequencies.

Figure 17 also supports the findings. This chart depicts the relative frequency distributions for the perceived importance of technical competence in each of the acquisition phases.

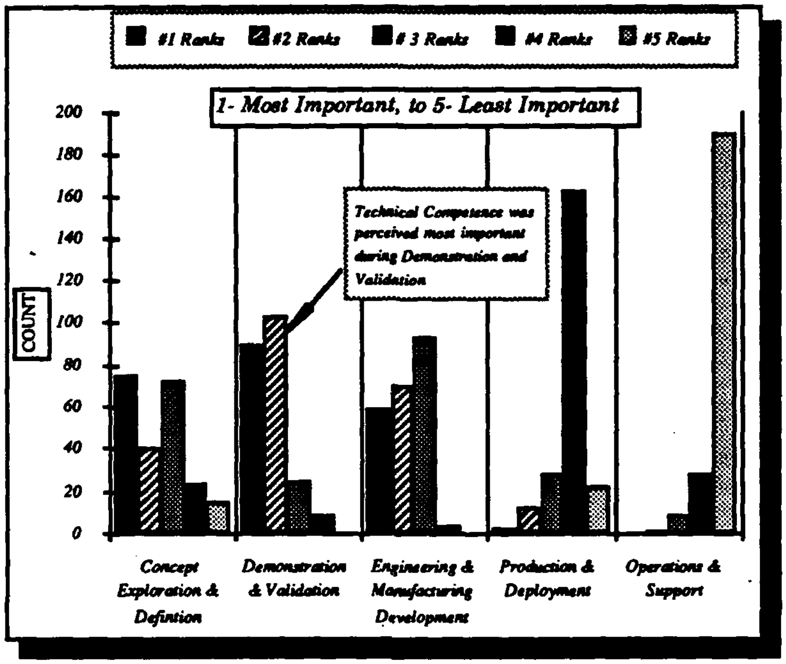


Figure 17. Perceived Importance of Technical Competence as a Function of Acquisition Phase: Relative Frequencies.

A multiple comparison, Appendix F, subsequently revealed where differences occurred between acquisition phases with regard to perceived importance of technical competence. Overall, the perceived importance of technical competence varied measurably among all acquisition phases, with Demonstration & Validation proving to be the phase where technical competence was most important.

Hypothesis #15. Acquisition managers perceive personal aptitude for seeking and understanding technical information as the best way to develop technical competency.

In testing this hypothesis, the Friedman two-way analysis of variance revealed a p-value equal to .0001, supporting rejection of the null hypothesis at .05 level of significance. Figure 18 presents the mean rankings for each of the development methods. Appendix D provides a chart illustrating the frequency distributions for the perceived importance of the various development methods.

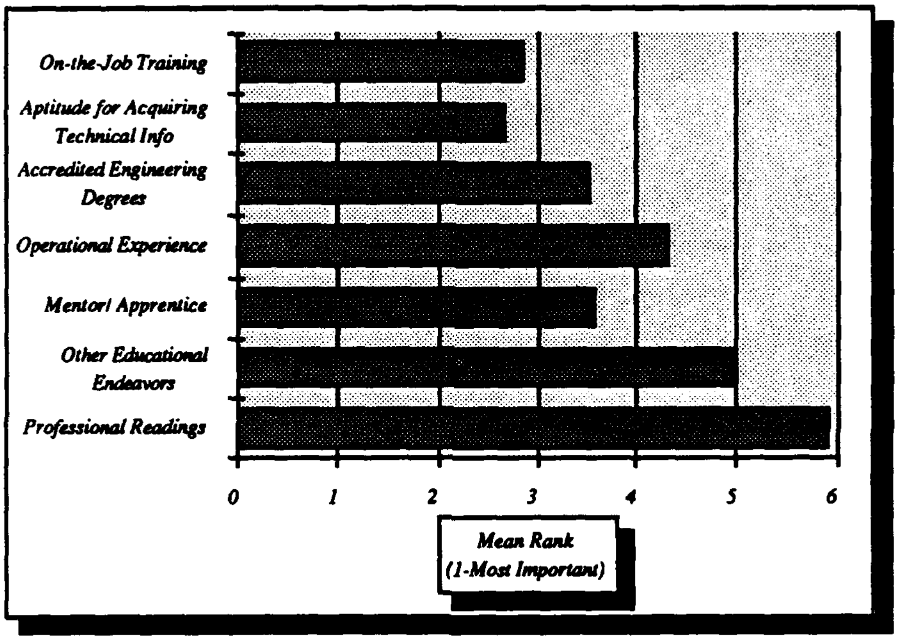


Figure 18. Mean Rankings of the Perceived Importance of Various Means of Developing Technical Competency: Frequency Distributions.

As Appendix F shows, the multiple comparison performed revealed differences among several of the methods to develop technical competency. Most important, the test indicated on-the-job training and an individual's aptitude in soliciting and acquiring information on technical issues as the methods believed to contribute most toward developing technical competency. The results indicated Mentor/Apprenticing and Accredited Engineering Degrees as the next best methods.

Hypothesis #16. Acquisition managers with less technical education perceive personal aptitude for seeking and understanding technical information more important in developing technical competency.

The Kruskal-Wallis test to evaluate the null for this hypothesis produced a p-value of .40 and failure to reject the null at a .05 level of significance.

Hypothesis #17. Acquisition managers perceive technical competence important to their interpersonal skills.

Descriptive statistics reported in Appendix D provided the basis for examining this hypothesis. The most frequent response observed revealed acquisition managers perceived technical competence as extremely important to their interpersonal skills. As shown in Figure 19, over 42 percent of the acquisition managers chose this response.

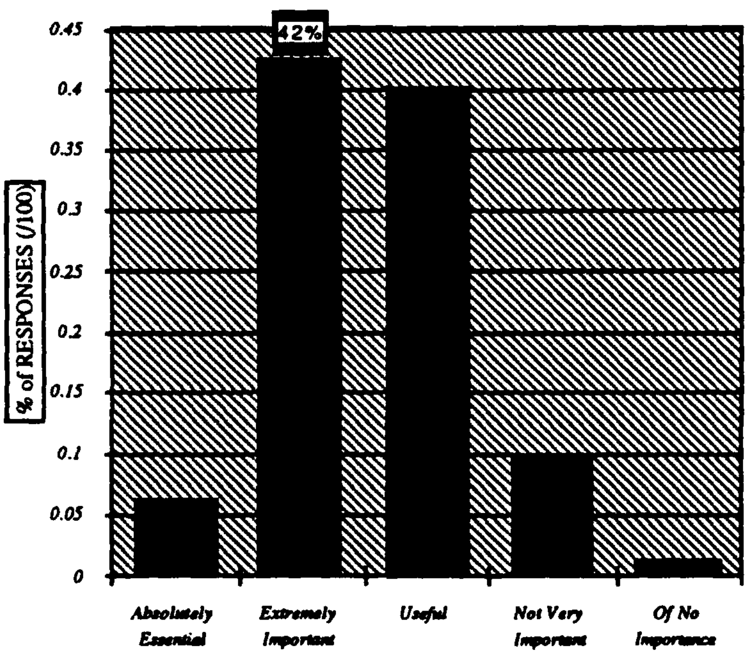


Figure19. Perceived Importance of Technical Competence to Interpersonal Skills: Relative Frequency Distributions.

Other Tests

Besides the aforementioned tests, two additional Friedman tests provided information on the relative importance of various skills with regard to project success and in terms of the extent of use in project activities. In both cases, tests produced p-values of .0001 supporting rejection of the associated null hypotheses:

- H_0 18: On average, no difference exists among the perceived importance of various skills to project success.

- H_0 19: On average, no difference exists among the perceived importance of various skills based on the extent of use in project activities.

Figures 20 and 21, respectively, describe the mean rankings for each of the various skills in the context of these hypotheses.

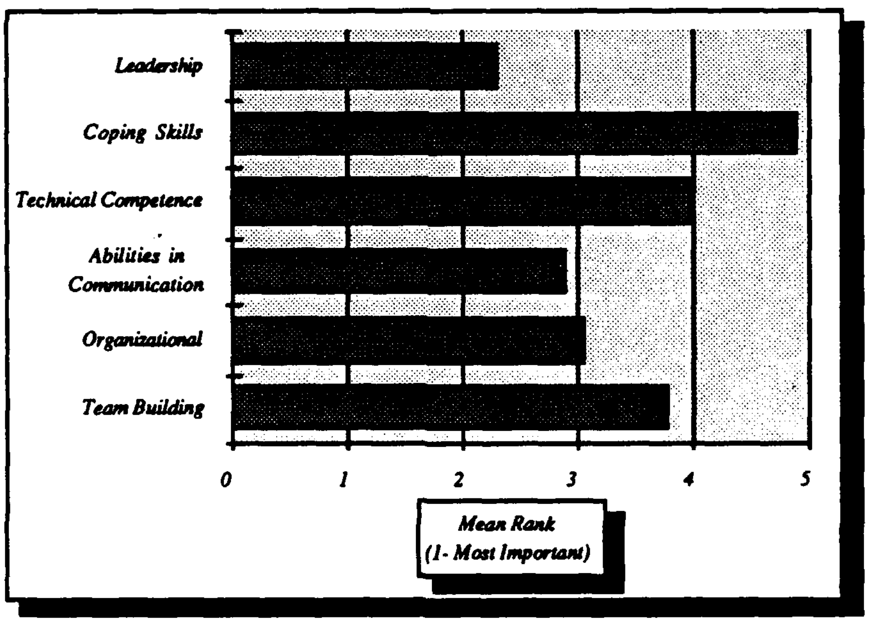


Figure 20. Mean Ranks of Various Skills Relative to Perceived Importance to Project Success

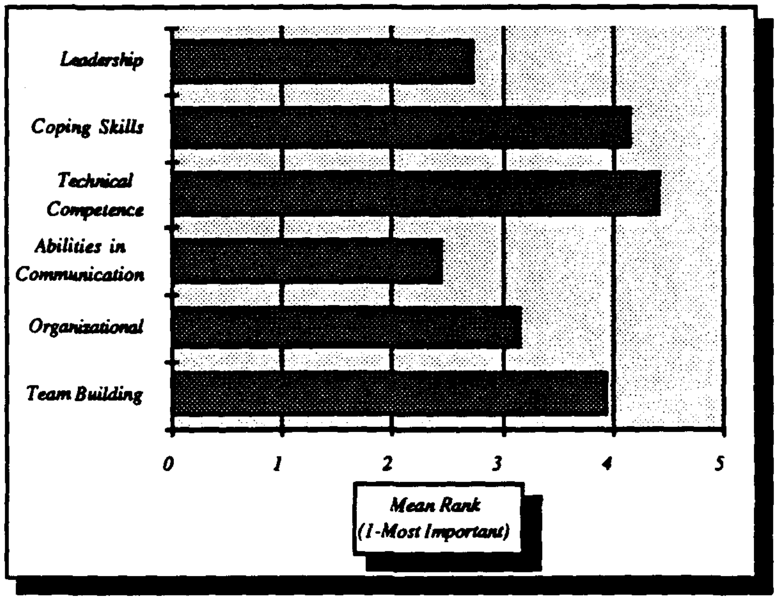


Figure 21. Mean Ranks of Various Skills, Based on Extent of Use in Project Activities

Frequency distributions for each of the various skills in the context of these two hypotheses are reported in Appendix D.

Multiple comparisons for each hypothesis, Appendix F, revealed the skill groupings within which no statistically significant difference existed. For Hypothesis #18, the results indicated organizational skills and abilities in communication as equal in perceived importance to project success. Technical competence and team building were also found indistinguishable. For Hypothesis #19, several pairs of skills were found relatively equal in terms of use in project activities. These are identified in Appendix F. In both cases, however, *Leadership* and *Abilities in Communication* represented the top two skills in terms of use in project activities and perceived importance to project success.

Summary of Findings

This chapter contained the results of the hypotheses testing, revealed the significant findings from the research, and identified areas which may deserve further investigation. Table 25 summarizes the significant findings of this study.

TABLE 25

Summary of Significant Findings

# of Hypothesis	Finding
1	Technical competence is extremely important or absolutely essential to a majority of acquisition managers, regardless of experience level.
5	Technical competence is perceived equally important by acquisition managers with the best technical project team members and those with the least capable technical project team members. Technical competence is perceived to be more important to acquisition managers with extremely good teams or mediocre teams, than it is to managers of reasonably good teams.
11	Acquisition managers with the most technical academic training perceive technical competence as more important than those with the least technical education
14	The perceived importance of technical competence varies as a function of acquisition phase. Further, technical competence is perceived most important during Demonstration & Validation, and generally perceived to be less important during later phases.
15	Acquisition managers perceive On-the-Job training and aptitude for acquiring and learning technical information as the more important methods of developing technical competence.
17	A majority of acquisition managers perceive technical competence is an important contributor to interpersonal skills.
18	Among several skills, acquisition managers perceive Leadership and Abilities in Communication as the more important skills relative to impact on project success.
19	Among several skills, acquisition managers perceive Leadership and Abilities in Communication as the more important skills relative to the extent skills are used in project activities.

Chapter V presents a summary of this research. Implications of findings and study limitations are discussed, and suggestions for future research proposed.

V. Discussion & Conclusions

Introduction

"Too few government managers have the necessary understanding, skills, and experience... to manage the acquisition process effectively" (Fox, 1990: 12). Indeed, what do acquisition managers perceive as the understanding, skills, and experience required to manage the acquisition process effectively? Do their perceptions about the importance of various skills and competencies required to successfully manage projects vary? This final chapter discusses the results of examining one particular element within the scope of these questions; the perceptions acquisition managers have about the importance of technical competence and how various factors may influence those perceptions.

The significant findings of this research, those supported statistically by the tests performed, are reviewed in context of the research questions put forth for this study. In the process, applicable comparisons are drawn with relevant suppositions found in literature. Implications are suggested accordingly. Additionally, this chapter reports a majority of the comments provided by respondents in an effort to provide more insight into the views of issues directly associated with the research topic.

The discussion begins by addressing the results associated with the overall perceived importance of technical competence in acquisition management. Subsequent sections focus on the findings associated with investigation of the remaining research questions. The later portion of this chapter discusses the implications of the findings, reports on respondents' comments, and provides suggestions and recommendations for future

research. Based on the results, the study has the potential to provide acquisition project managers a better understanding of the perceived importance of technical competence and how perceptions may vary as a result of various factors.

Perceived Importance of Technical Competence

One of the main objectives of this research involved examination of the perceived importance of technical competence among acquisition managers. The ongoing growth of technological innovation and complexity within industry and project environments justified investigation of this issue.

As revealed in Chapter IV, the study supported the conclusion that acquisition managers perceive technical competence to be extremely important. The attribute was believed among the majority of acquisition managers to frequently make the difference in their ability to manage projects.

Notably, review of the literature provided no definitive basis for making a proposition about the perceived importance of technical competence. Although several studies describe technical competence as an important attribute, an equal number do not in lieu of highlighting the potential importance of other attributes. Lack of agreement across studies therefore prevented any broad generalization about the perceived importance of technical competence which might apply to acquisition project managers. Review of literature and the content area discussions performed for this study did however, reveal factors which might influence the perceived importance of technical competence:

- experience
- level of project technology
- technical education
- caliber of technical project teams
- acquisition phase.

The next sections discuss the significant results obtained from investigating these factors.

Individual and Situational Factors of Influence

The study revealed significant findings only in three of the five factors:

- technical education
- caliber of technical project teams
- acquisition phase.

Technical Education. A significant relationship was found between technical academic training and the perceived importance of technical competence. The study revealed acquisition managers with the most technical academic training perceived technical competence more important in comparison to those with the least technical education. Further, qualitatively the responses of the most technically educated acquisition managers suggested they used technical competence more often relative to other skills and also considered technical competence more consequential to project success. Review of the literature did not provide a strong basis for predicting this outcome even though it may seem quite logical. On the contrary, many studies of engineering students and recent graduates of engineering programs have shown technical individuals are placing a rather substantial level of importance on general management

skills (Guteral, 1984). Nonetheless, the more technically educated might certainly be expected to perceive technical competence more important relative to those with much less technical education. However, personal bias may not necessarily be the cause. The more technically educated may well perceive technical competence more important as a result of (1) having been involved in more technically complex projects and (2) consequently having had to develop technical competence to be effective in the more technical projects. Notwithstanding, even though the least technically educated respondents perceived technical competence less important by comparison, the majority of these individuals nevertheless perceived technical competence to be extremely important. Perhaps, the results may simply reflect a difference in level of appreciation for technical competence. Those with less technical academic training may not be in a comparable position to judge by experience the importance of technical competence.

Caliber of Technical Project Teams. The data analyses revealed acquisition managers with the best technical project team members and those with the least capable technical project teams, perceived technical competence equally important. Additionally, the responses of these groups qualitatively suggested they may use technical competence more often relative to other skills and consider technical competence more consequential to project success. Perhaps more significant, these two groups perceived technical competence more important than acquisition managers with technical project teams of Reasonably Good or average capability. Several explanations are possible.

First, acquisition project managers with the better technical project teams may perceive technical competence more important because they

have a greater need to communicate effectively on technical issues. The need for credibility, an ability to influence technical team members, and provide technical leadership may also have been factors, as revealed in review of the literature (Hodgetts, 1968; Gemmill & Thamhain, 1973; Pitts, 1990). The project managers with the most capable teams may also have perceived technical competence more important because the attribute contributed to their team building efforts (Thamhain & Wilemon, 1987). On the other hand, those acquisition project managers with the least qualified teams may perceive technical competence more important (1) because their teams are not technically competent, and they are doing much of the technical work themselves, or (2) because their teams are not technically competent and neither are the managers themselves, who wish they had the technical know-how to handle the technical issues.

Acquisition Phase. Technical competence was also found to be more important during particular phases of the acquisition process. Acquisition managers perceived technical competence was most critical during Demonstration and Validation, one of the earlier phases in the acquisition process. The literature provides many sources indicating comparable findings (Pinto & Slevin, 1988b; Smythe & McMullan, 1975; Spitz, 1982). Among various industries and organizations, the importance of technical competence has been shown to vary as a function of the periods in project life cycles. And frequently, technical competence has been shown to be more important early in project life cycles (Smythe & McMullan, 1975; Spitz, 1982). Possible explanations extend from consideration of the activities occurring during the earlier phases and the different types of conflict (Posner, 1986; Thamhain & Wilemon, 1975). In acquisition

projects, technical competence may be perceived more important during the Demonstration & Validation phase because a majority of the activities during this period involve extensive evaluation, test, and analysis of a weapon system's development and operating characteristics.

Importance of Technical Competence Relative to Other Skills

In addition to examining how the perceived importance of technical competence varied as a function of personal and situational factors, this study also investigated how the perceived importance of technical competence varied relative to other skills. As an individual attribute, the study supported the conclusion that acquisition managers perceived technical competence extremely important. Considering the results observed when technical competence was rated among other skills, this finding seems somewhat contradictory. In terms of use in project activities, the study indicated technical competence was among the skills least used. Leadership and abilities in communication represented the skills respondents reported they used most. Relative to project success, technical competence also ranked among the skills perceived least important. Leadership and abilities in communication again appeared the more important.

These results are significant. The findings provide a reasonable explanation for why other studies have not revealed technical competence as important. Many have examined the importance of various skills in terms of the extent project managers use them. In this context, skills like communication frequently are the most significant. Project managers do spend a majority of their time communicating (Posner & Randolph, 1988;

Thornberry & Weintraub, 1983). Further, because most of a project manager's time is normally spent communicating, an inability to communicate might easily be considered more consequential to project success. The reason other skills like leadership, may also rank high in the two perspectives is possibly the result of a relationship to communication abilities. Interestingly enough, when acquisition managers were asked how important technical competence was to their interpersonal skills, the majority identified the attribute as extremely important.

Developing Technical Competence

Although not a central issue of this study, part of the research involved investigation of the importance acquisition managers attached to various means of developing technical competence. Assuming the attribute was found important, it seemed worthwhile to assess what the acquisition workforce considered as the methods which contributed most to developing technical competence. The study revealed on-the-job training and an individual's aptitude for acquiring technical information as the better methods. This finding substantiates similar conclusions in previous studies of project managers (Stuckenbruck, 1976; Thornberry, 1987). Considering on-the-job training and aptitude for acquiring technical information are so closely aligned with staying on-the-job, the results may suggest these are the better means of not only becoming up-to-date on technology, but remaining technically current as well.

Implications of Findings

The significant findings of this study provide a basis for several implications primarily related to selection, training, and education of

acquisition managers. The fact technical competence was perceived extremely important by the majority of acquisition managers of all AFSCs, all experience levels, and all levels of technical education implies the attribute should be considered when choosing individuals for the acquisition corps assigning acquisition managers to projects.

In addition, the results indicated the caliber of technical team members may need to be considered when assigning acquisition managers to projects. Technical competence appears very important to acquisition managers in working with the best technical project teams. At the same time, the results imply acquisition managers may need some level of technical competence in order to compensate for a lack of capability among technical project teams. Equally substantial perhaps, the findings here indicate the importance of selecting capable individuals as members of technical project teams. Without a sufficiently qualified team, an acquisition project manager may become unnecessarily involved in the technical issues of the project.

The study also revealed the most technically educated acquisition project managers perceived technical competence more important. Just as significant it seems, is the fact even the least technically educated respondents perceived technical competence to be extremely important. This finding implies it may be vital for the majority of acquisition managers to have a general understanding of technical concepts and/or the aptitude and ability to acquire an understanding of technical concepts, because of the relatively technical nature of acquisition projects.

Further, the research showed acquisition managers as perceiving technical competence most important during the Demonstration &

Validation phase of the acquisition process. The supposition here is technical problems prevail at this time. As such, if turnover is likely to occur in managing the project, assigning a technically competent project manager at this point would probably contribute more to the success of the project.

Also significant, in assessing technical competence relative to other skills, leadership and communication were found most important to acquisition project managers. Considering this finding and the several studies (Brown, 1976; Bennett & McMullen, 1987; Given, 1955) indicating individuals with technical backgrounds are often weak in communication skills, perhaps a communications training program is in order for new acquisition managers. With the importance attributed to leadership, perhaps less emphasis should be placed on acquisition officers being recognized as managers. Such a reform in attitude may improve motivation among the acquisition corps.

Development of technical competence was another where the research revealed significant findings. Acquisition project managers indicated on-the-job training and aptitude for acquiring technical information as the methods contributing most to development of technical competence. Aptitude and on-the-job training are undoubtedly significant to learning. Considering project managers across all experience levels perceived technical competence extremely important or absolutely essential, an ability and process to learn things technical is apparently important. Given a individual has the aptitude, perhaps on-the-job training may be a successful avenue for educating acquisition managers on other aspects of the acquisition process as well.

Respondents' Comments

This section provides excerpts of various statements made by respondents for consideration and use in developing follow-on studies. Altogether, the comments respondents provided offer additional insight into acquisition managers' perceptions of technical competence. Further, several of the statements substantiate previous research and support the findings in this study. The body of comments obtained reflect many different opinions. The variety of opinions is particularly noteworthy considering the general consensus on the perceived importance of technical competence among the sample of acquisition managers. While the comments cover a variety of issues, a majority of the statements relate to project teams and team building. Interestingly enough, in the analysis of technical competence relative to other skills in this study, team building proved one to be one of the skills respondents ranked least important. Perhaps this highlights the need for a more definitive or generic framework for assessing the importance of skills. The interrelationships between many skills often makes it very difficult for respondents to accurately identify what they perceive as the most important attributes. A level of skill categorization which eliminates the overlap in relationships between attributes would prove extremely useful in future research.

The respondents' comments overall revealed several issues:

- the common contention about technical education equating to technical competence
- technical competence embodies several aspects and abilities

- technical competence may be important, and the requirement for technical competence may vary
- technical competence may contribute to credibility
- a combination of skills are generally required
- team building seems to be the focus of effective performance
- competent technical teams free managers to lead projects
- technical team members may benefit from management training
- some acquisition managers may be too involved in technical issues
- technical competence may contribute to an ability to communicate
- technical competence can be developed

Technical Degrees and Technical Competence.

An acquisition manager with more than eight years experience states:

> I feel technical competence, i.e., an engineering degree, is extremely important to successful management of the types of programs within Air Force Systems Command.

A project manager with a strong engineering background suggests:

> Anyone laboring under the idea that technical competence, i.e., an engineering degree is required for a program manager is wrong, wrong, wrong and is merely perpetuating a myth. Good managers/leaders can have all types of backgrounds, from music to physics. The real key is do they know the right questions to ask, and can they sort out people they can trust (functionally competent) from people they can't. There are many technical people that fit into the former category. It does not follow that an engineering degree equals technical competence, equals a good program manager.

Another project manager, one rating technical competence extremely important, writes:

> I disagree with the concept an engineering background is required for program management. A background in leadership, coupled with the ability to understand what is happening and the willingness to solicit aid from the proper

> team players is the most important attribute anyone in program management can have. Engineers handle engineering-PMs manage the program or project.

A simpler, insightful comment was provided by one of the program directors, he states, "If you don't have a technical background, you can't be a program manager...not necessarily so."

Acquisition Experience. With regard to the importance of technical competence relative to experience and level of responsibility, one of the program directors suggests:

> The importance of technical competence to project success depends on the level of responsibility... the higher the level, the less important.... It depends on whether you are a project officer, 3-ltr director or SPO director.... I would expect a lieutenant or captain to be more reliant on technical competence for work assigned.

One of the junior project managers provides a somewhat different opinion:

> As a 2724 project manager and a degreed engineer, I don't often apply technical training skills (i.e. engineering) on the job... it just isn't needed. In fact, all program managers (lieutenant through lieutenant colonel) require only a superficial knowledge of sound engineering principles.

Acquisition Phase. With respect to the importance of technical competence relative to acquisition phase, two program directors make the following comments. One states, "Technical competence is equally important in all phases." Similarly, the other writes, "In a technical business you need to have technical competence... during all the acquisition phases."

Technical Competence and Credibility. Several respondents indicate technical competence contributes to an acquisition manager's credibility.

An intermediate level project manager states, "Some technical competency is essential for credibility as a manager." Another of equal experience writes:

> Technical competency establishes credibility and relays experience and understanding in a technical area. In management, it is not the most important attribute... but it is very important. Leadership and organizational skills are essential in program/project management. In functional areas, engineering, manufacturing, contracts, configuration control, etc... technical competency is the most important attribute. Managers depend upon their functional team to provide them the highest level of technical competency to ensure effective project management.

Note the statement about the functional team. A myriad of comments highlighted the importance of building teams, effectively using teams, and the need for competent technical project teams.

Technical Competence and Project Teams.

The essence of successful acquisition management centers on the project team, as expressed by an experienced project manager with a broad technical background:

> I've learned that acquisition management is all about: getting people to do (leadership), the right things correctly (technical competence), at the appropriate time (management), to achieve program goals and objectives (mission-oriented). Effective program managers lead people, manage resources and time, understand the technical aspects of their programs, and focus all their team's energy and efforts towards successfully accomplishing the mission.

A good project team and team building are important. A midlevel project manager with a considerable technical academic background writes:

> Great acquisition officers must have complete competency in leadership, communications, and technical expertise. If you have a good team, goals can be accomplished more readily. We in the acquisition business must foster a product-oriented team building led by a strong and capable individual.

Some project teams appear to lack important nontechnical skills. The statements of one acquisition manager imply technical project team members need to develop more of a management perspective:

> If you organize, communicate, and lead well a well-built team results. Though my team members usually possess the technical competence within their area, they frequently don't do well at applying their competence to developing/recommending alternative courses of action; understanding they are responsible for posing "what if" questions in their area. I believe coursework should do a better job at teaching team members how to be better team players, i.e., ask questions, research possible courses of action, develop and recommend alternative approaches. Some people (team members) never seem to consider how the information in their area will be used in context of the overall program. Sometimes I have to pull teeth to get team members to give me options/and an inchstone schedule that supports accomplishing those options.

Another project manager in a high-technology program provides similar remarks, indicating acquisition managers need technical competence to compensate for technical project team members who lack a management perspective:

> I believe that it is absolutely essential for the acquisition manager to have a technical background (i.e., B.S. in engineering) Even if your project team had technically competent engineering support, these people tend to lack the managerial skills needed to master technical issues. They often fail to ask the right questions and can't make the programmatic decisions needed to resolve the problem. Unless your engineers are good managers, the program manager without a technical background will have a serious handicap while managing a technical effort.

In addition, according to one project manager, the technical specialists on some project teams require more practical experience:

> Supposed experts on the project team are rare in government service. Most engineers have never been hands-on in their

> business. That leads an acquisition team to rely on the technical competence and recommendations of the contractor.

With focus on the relationships between project managers and functional managers, an intermediate acquisition manager reveals one of the potential problems with being a technically expert project manager:

> In general, the technical people are competent, which should enable the project managers to focus more on their leadership instead of micro-managing the technical managers. But in many cases the PMs don't.

Another midlevel acquisition manager with a limited technical academic background suggests technical know-how can cause problems too:

> ...you need a business manager to pull together the entire program and program team, not someone who gets bogged down in the technical details. They need to be able to get out of the forest.

A junior acquisition manager also points out the potential drawbacks of a project manager with extensive technical expertise, and the introduces the importance of having a qualified project team to rely on:

> Technical knowledge is important, but only general technical knowledge is necessary in my opinion. Expert knowledge, I have found, tends to make people more limited in their ability to choose/offer options. An acquisition manager never needs to be an expert in any area if they have responsible and technically competent functional experts helping. The most important thing about technical knowledge is the ability to understand the options being presented to you and the ability to recognize when things don't look right. More important than that though is the ability to evaluate all areas of acquisition and to determine a choice of actions based on impacts in all areas.

An acquisition manager in a state-of-the-art project further emphasizes the importance of having a technically qualified project team, in addition to suggesting acquisition managers require at least a cursory understanding of technical concepts:

> It is critical to have technical competence on your team. It's not critical for the PM to be technically competent, but he needs a general understanding of the "laws of physics" and the technology he's dealing with.

Several other respondents also relate the importance of having some degree of technical competence, balanced with a willingness to rely on the technical expertise of the project team. A midlevel project manager with an extensive technical background explains:

> My technical skills allow me to understand what the technical issues are but the engineers really are the ones to handle these issues. If the program isn't organized and focused, no amount of technical expertise will save it from problems... organizational skills are crucial for effective acquisition management.

An intermediate level acquisition manager in an experimental technology project states:

> Leadership, team building, and organization are really hard to separate-not sure you can. Technical competence is important for program managers, but keep in mind it is not their field. Engineers support the program manager and should work as a tight team to ensure effective management. Unfortunately, the engineering division often wants to be in charge. They need to realize they are a support organization, just like contracts, program control, test, logistics, etc. You have to adjust to the program and take on a new management style.

Another project manager of less than eight years experience, some technical education, and working in an experimental technology program, writes:

> In my experience only about half of the managers are engineers by degree. A successful manager is one that can use the skills of the team he leads. Successful managers need good communication skills and the ability to ask the hard questions, but not necessarily in-depth knowledge of the technology. Most schools don't prepare engineers for DoD engineering skills needed. Software engineering, mil specs, etc., are learned by on-the-job training.

Technical Competence Among Other Skills. A few of the respondents made remarks relative to the importance of technical competence in the context of other skills. One of the senior acquisition officers describes the need for a balance of skills:

> Acquisition management is a multi-dimensional subject. There is no doubt in my mind that technical competency is a critical element, no more or less important than any of the others. A program manager who does not have equally strong technical, personal, leadership, etc skills will generally not be the most effective program manager.

A junior project manager provides additional insight:

> While I ranked technical competence as essential, you saw I gave it a lower ranking amidst the classic leader/manager skills. This is not contradictory. I rely very much upon my technical training and background to explore issues, examine other's ideas, and question technical approaches. But, because I have this foundation it is second nature to me and I am free to concentrate on taking care of my people so they can take care of the mission. With the technical complexity of our systems, it is becoming increasingly important to have generalist program directors with a technical foundation. I suspect respondents with a non-technical background might worry more about technical issues--its particularly unnerving when you don't know the right questions to ask. But this can be true for any discipline--the question is which ones will kill you more often.

Another more experienced project manager provides similar remarks:

> ...does technical competency equate to good program management? Technical competency is merely an added skill/knowledge we can carry to a program just like experience, good communication skills, etc. Many of our systems are so complex today, some technical competency is required to understand and communicate with our contemporaries on our programs. In some programs, technical ability is essential to assessing technical adequacy, impact on cost, schedule, and risk.

A second midlevel acquisition officer offers support of the assertion some measure of technical competence is important:

> I have a management background and have not kept current with technology... this has had some negative impact on my capability to manage.

Although in partial agreement, one project manager suggests other skills may compensate for a lack of technical competence:

> For me, management of a technical program becomes easier as technical competency increases. This is not to say that someone who is not up on the technology cannot manage. Interpersonal skills is a big player...

In stark contrast, yet another acquisition manager, one with considerable technical academic training, asserts technical competence may be of little importance relative to the impact of other attributes:

> I believe leadership is the key. It doesn't matter how technically superior a person may be if they can motivate others or provide the vision. I have worked with some brilliant engineers who were very poor leaders. Our work suffered because these brilliant engineers were promoted to supervisory roles. Without a strong leader, all you will have is a bunch of frustrated people.

The classic opinion was also made however:

> I believe several skills must be interwoven throughout the management of all projects co-equally to obtain a successful conclusion...

Descriptions of Technical Competence. Some comments were also made describing technical competence as a multi-faceted attribute, aspects of which are developed through a combination of methods:

> Technical competency is that rare blend of engineering know-how (generally taught and built on with experience), plus management and leadership acumen (generally caught from mentor and added to with experience and schooling), plus an understanding of programmatics (combination of AFIT/DSMC, experience, and OJT). Missing any one of the three makes you technically deficient.

Similarly:

> Technical competence is one part scientific (engineering disciplines), one part operational understanding (of weapon systems & requirements) and one part acquisition processes (PPBS, RFP, testing, etc). I think a balanced understanding in all of these areas of "technical" is desired of a good (competent) acquisition manager. Acquisition training should be tailored to an individual's background (engineer/rated/manager). Generally, new rated program manager types need to catch up on the processes whereas new "technical" program manager types need to better understand operational requirements.

Research Limitations & Recommendations for Future Studies

Several significant findings resulted from this study. Many explanations for the significant relationships found between various factors and perceptions of the importance of technical competence have been offered. Some implications have likewise been suggested. The ability to do either rests on the confidence placed in the reliability and validity of the results, and an assumption about the generalizability of the findings. Considering the sample size acquired, the level of response, and examination of the potential for nonresponse bias, the study sample was considered representative of the study population. As a result, generalizing the results to the study population is defendable. To the extent the population of acquisition managers represents other groups of acquisition officers, the results of the study should be equally generalizable. The variables represented in the study are certainly generalizable among other product divisions (i.e., Electronics Systems Division, Space Division, etc.).

With regard to specific recommendations for future research, several suggestions are offered for consideration.

- Further investigation is needed. Because the study was *ex post facto*, and not a causal study, the significant relationships found among

research variables may not necessarily imply causality. However, this study as *ex post facto* may provide the foundation for determining causality among the same variables in future studies (Emory, 1985). A follow-on study is recommended with a research design and data collection method oriented to directly investigate why acquisition managers perceive technical competence important and why perceptions vary as a function of different factors. Such a study should attempt to couch the investigation of technical competence in terms of a general examination of what types of problems acquisition managers experience, what attributes allow them to effectively handle the problems, what acquisition managers believe they are lacking in terms of dealing with project issues, and how they believe their abilities could be improved.

- Subsequent studies might include product divisions in an attempt to determine if differences in perceptions exist among locations.

- A parallel study of civilian acquisition managers and military acquisition managers would offer several interesting possibilities with regard to investigating the issue of technical competence. Another variation would be to conduct a study of technical specialists and engineers who might qualify for project management positions. Perhaps some emphasis should be placed on exploring the importance of technical team members' abilities (e.g., how effectively they communicate with project managers).

- Follow-on studies might focus on determining how organizational differences influence the need for technical competence. Several studies indicate technical expertise serves as a strong basis for establishing

authority in projects (Einseidel, 1987; Pitts, 1990; Wojick, 1989). Is technical competence more important in matrix organizations?

- Interviews might prove a beneficial supplement to any mail survey conducted. Comments received in response to the open-ended question in the survey instruments for this study were both interesting and informative.

- A conceptual framework which clearly delineates skills needs to be established for assessing the importance of various attributes. The perceived interrelationships between various skills like communication skills and team building present difficulties in accurately assessing their importance.

- This research perhaps provides enough information about the study population to confidently justify use of parametric tests in future research. If the assumptions for use of parametrics can be met, the power of these tests may support more definitive results, particularly in the cases where this study produced weak acceptance of the null hypothesis.

- Developing or adapting an instrument like the California Psychological Inventory "good manager" scale (Gough, 1984) to study project manager competence may also prove interesting and potentially beneficial to selection of acquisition managers.

- Investigating and developing a series of interest scales (Strong, 1927) for acquisition project managers might also prove valuable towards examining acquisition managers as a group.

- In this study, acquisition project managers indicated leadership and abilities in communication were significant to project success. Some studies, like the one conducted by Decotis, Dyer and Hundert (1976) revealed

otherwise. An examination to determine whether certain skills are more important in the military project environment might prove useful.

- IEEE Engineering Skills Assessment Program (Willis, 1990) may provide a basis for developing a skills assessment package for professional acquisition officers.

Appendix A: Project Manager Study Summaries

Author (s) and Year	Gaddis (1959: 89 - 97)	Hodgetts (1968: 211 - 219)	Stuckenbruck (1976b: 40 - 47)
Method of Investigation	Field research	Interviews Questionnaires	Field Research
Subjects		Project managers in 56 firms among aerospace, construction, chemicals, and state gov't fields	
Attributes	Career must be molded in the advanced-technology environment Working knowledge of many fields of science... basic level, augmentable to work in specific technologies Good understanding of general management problems Strong, continuous, active interest in teaching, training others	Leadership techniques: Technical Competence Personality/ persuasive ability Negotiation Reciprocal Favors	Multi-disciplinary Oriented Total Problem Oriented Effective Problem Solver Manager and Administrator Skilled Analyst Creative Communicator Motivator Flexible Right Temperament
Technical Competence	PM must be capable of both integration and analysis, and must understand the training of professional technologists and their emphasis on analysis... PM cannot be expected to double as a member of the executive committee and as a scientist equally well	Within the aerospace industry, technical competence was found "very important" to project managers as a technique for overcoming their authority gap... techniques used were found to vary with project size... the larger the projects . the more formal authority given	Technical skill in principle project discipline required Generalist Technical education, background, and experience commensurate with level of project technology
Development of Technical Competence			

Author (s) and Year	Thamhain & Wilemon (1978: 100 - 104)	Thornberry &Weintraub (1983: 73 - 76)	Posner (1987: 51 - 54)
Method of Investigation	Field research	Activity Log Interviews-critical incidents Skills Query Personality Test	Questionnaires during seminars
Subjects		110 male project managers among 8 high-technology firms	287 project managers (189 men, 98 women) from a variety of technology-oriented organizations
Attributes	Team building Leadership Conflict resolution Technical expertise Planning Organization Entrepreneurship Administration Management support Resource allocation	Oral communications Influencing Skills (Leadership) Intellectual Capabilities Handling Stress (Conflict resolution) Works Skills (Planning & Organizing)	Communication Skills Organizational Skills Team Building Skills Leadership Skills Coping Skills Technological Skills
Technical Competence	PM must relate socially as well as technically... PM should understand the technology, the markets, and environment of the business to participate effectively in finding integrated solutions and technological innovations, and to evaluate technical solutions, assess risks, and to communicate effectively in technical terms Right mixture of skills depends on project, people, and organizational structure	Effective project managers delegated technical and other work	Successful project managers were seen as having relevant experience or knowledge about the technology required by the project... effective PMs not often viewed as the technical expert... decreases flexibility helpful only to the extent it improves communication, teambuilding, leadership...
Development of Technical Competence	Developed through progressive growth in engineering or supportive project assignments in a specific technology area		

Author (s) and Year	Einsiedel (1987: 51 - 56)	Cleland (1988: 49 - 56)	Thamhain (1989: 652 - 659)
Method of Investigation	Field Research	Review of Corporate Project Managers comments on organizational culture	Field investigation Interviews Review of training & development records
Subjects			220 project managers among 18 companies of 6 business fields
Attributes	Credibility, a combination of expertise and trustworthiness Creative Problem-solver Tolerance for Ambiguity... uncertainty Flexible Management Style Effective Communication Skills	Comfortable an in environment of high uncertainty Problem-oriented (technical, administrative, schedule, cost) Positive outlook, enthusiastic, "can-do" attitude Skill to apply experience, knowledge to project requirements and problems	Technical Administrative Interpersonal/ Leadership
Technical Competence	it is a significant asset to a project manager to have the specialized technical *education or training* as well as a *track* record of successful project management relevant to the current project	Basis of a person's authority will come from knowledge, skill, personal *effectiveness*, and *attitudes* more than from legitimacy of an organizational position.	Technical expertise necessary to communicate effectively with the project team, assess risks, and make trade-offs between cost, schedule, and technical, issues
Development of Technical Competence	Of competencies in general... managing projects through trial and error, often with help from mentors, experience		Learnable vis on-the-job experience

Author (s) and Year	Rosenbaum (1990b: 24 - 26)	Cullen, Gadeken, Huvelle (1990: 26 - 31)	Pettersen (1991: 21 - 25)
Method of Investigation	Field Research	Interviews, data from transcripts	Literature Review, 15 years of studies
Subjects	technical project managers	52 program managers from Army, Navy, and Air Force acquisition commands	
Attributes	Adept at dealing with: • Surprise and frequent change • Competition for resources • Conflicting goals • Overlapping responsibilities • Sensitive to organizational & political issues Critical Communication Skills: • Tracking skills... awareness of others • Reading Cues ... assessing others actions • Empathizing... listening & confirming • Testing for Acceptance... reactions • Persuasive Skills • Clarifying Needs... of others • Communicating Benefits • Gaining Commitment Shaping Skills • Reinforcing Positive Responses • Creating Need Awareness • Handling Objections	Managing the External Environment • Sense of Ownership/Mission • Political awareness • Relationship development • Strategic Influence • Interpersonal Assessment • Assertiveness Managing the Internal Environment • Managerial Orientation • Results Orientation • Critical Inquiry Managing for Enhanced Performance • Long-term Perspective • Focus on Excellence • Innovativeness/Initiative • Systematic Thinking Proactivity • Action Orientation • Proactive Information Gathering	Problem Solving & Administration • Problem Analysis • Judgement & Practical Sense • Decisiveness • Planning & Organization, Control • Strategy & Organizational Know-How • Specialized Knowledge Supervision & Project Team Management • Delegation of Responsibilities • Team Structuring • Consideration Towards Team Members • Development of Team Members • Teamwork, Flexibility & Cooperation • Resolving Conflicts Interpersonal Relations • Oral Communication • Interpersonal Influence, Negotiation • Ascendancy Other Personal Qualities • Need to Achieve & Proactivity • Self-Confidence, Maturity, Stability • Loyalty, Honesty, Tolerate Ambiguity
Technical Competence	...high-tech age requires new levels of technical skill, but people skills all the more important... technical ability more significant in early years	Effective program managers master a few strategically important areas, and leave the mass of administrative and technical details to subordinates... acquisition professionals require different competencies (Gadeken, 1989b) than PMs... technical expertise #1	Specialized knowledge related to the technology to be used more important in smaller projects, technical aspects delegateable in larger projects, competence can promote credibility
Development of Technical Competence			In general, experience, on-the-job training, progressive process--different jobs at different levels

Appendix B: Survey Instruments

Questionnaire ASD Survey Control Number 91-371
Expires 1 Aug 91

1. Indicate the number of years experience you have in DoD acquisition:

    1. 3 years or less
    2. > 3 to < 8 years
    3. 8 years or more

2. Select the response most indicative of the technology involved in your project(s).

    1. Experimental--evolutionary... at the frontier of scientific and engineering knowledge... aspects, tools, and techniques have been demonstrated in lab environments or only simulated.

    2. State-of-the-art-- used, demonstrated, supported and available, but only through a limited number of sources (i.e., industries).

    3. State-of-the-practice technology-- in general use, well understood and characterized by a long record of use in industry.

3. Select the response which best describes the number of credit hours (undergraduate and graduate) you have in subjects which directly contributed to your technical competency:

    1. 25 credit hours or less
    2. > 25 but < 50 credit hours
    3. 50 to 90 credit hours
    4. > 90 but < 120 credit hours
    5. 120 or more credit hours

4. Select the description most indicative of the technical competence displayed by project team members you work with who are responsible for technical aspects of the project:

    1. Extremely good--they completely understand the technologies involved in the project, always deal effectively with the technical problems, and keep me on top of the technical issues.

    2. Reasonably good--they usually understand the technologies involved in the project, generally deal effectively with technical problems, and usually keep me out of trouble on technical issues.

    3. So-so--with some luck the team can grasp the basics of the technology involved, and can get the project through some technical problems with effort, but overall they do not demonstrate a level of expertise which makes me comfortable with their decisions.

    4. Poor--clueless most of the time... they lack the needed technical competence and for all the help they provide, I might as well be the project team.

5. Based on your cumulative experience, indicate how important Technical Competence is to you as an acquisition manager:

1. Absolutely essential, cannot effectively manage without it.
2. Extremely important, frequently makes the difference in my ability to manage.
3. Useful, occasionally significant to my ability to manage.
4. Not very important, rarely consequential to my ability to manage
5. Of no importance, can manage effectively without it.

6. Based on your experience, use a 1 to 6 scale (1-most consequential, 6-least consequential) and RANK the attributes/skills which follow to indicate the impact of each on overall project success:

_____ Organizational skills... planning, goal-setting, analyzing, etc.
_____ Abilities in communication ... listening, persuading, etc.
_____ Technical competence... ability to apply technical experience and knowledge, etc.
_____ Coping skills... patience, persistence, flexibility
_____ Leadership... influencing others, providing direction, vision, etc.
_____ Team building skills... fostering commitment, coaching

7. Recall the PHASES in the Acquisition Process (as outlined in DoD Directive 5000.1). Based upon your experience, RANK the acquisition phases below in the order which indicates when technical competence is most important. Use a 1 to 5 scale (1-technical competence is MOST important during this phase, 5- technical competence is LEAST important during this phase), and use each rank only ONCE. AFTER RANK ORDERING THE PHASES, place a check mark (√) beside any phase for which you may have inadequate experience.

_____ Concept Exploration & Definition
_____ Demonstration & Validation
_____ Engineering & Manufacturing Development
_____ Production & Deployment
_____ Operations & Support

8. Consider the factors which contribute to your technical competence. Using a 1 to 7 scale (1-most important, 7-least important), RANK the 7 items which follow to indicate the relative importance of each in developing your technical competency. Use each RANK only ONCE.

_____ Professional readings (e.g., journals like IEEE, periodicals, manuals, etc.)
_____ Other educational endeavors (e.g., additional college courses, seminars, etc.)
_____ Mentor- working/apprenticing under an authority/expert in acquisition management
_____ Operational experience
_____ Accredited undergraduate and graduate engineering degree programs.
_____ Your aptitude for asking questions and soliciting information on technical issues.
_____ On-the-job training

9. Based on your experience, use a 1 to 6 scale (1-use the most, 6-use the least) and RANK the attributes/skills which follow to indicate the relative amount of time you rely on them as an acquisition manager. Use each RANK only ONCE.

_____ Team building skills... fostering commitment, coaching
_____ Organizational skills... planning, goal-setting, analyzing, etc.
_____ Abilities in communication ... listening, persuading, etc.
_____ Coping skills... patience, persistence, flexibility
_____ Technical competence... ability to apply technical experience and knowledge, etc.
_____ Leadership... influencing others, providing direction, vision, etc.

10. Select the response which best describes how technical competency contributes to your interpersonal (human relations) skills:

1. Absolutely essential, cannot communicate effectively, negotiate issues, manage conflicts, bargain with others, or maintain rapport without it.
2. Extremely important, frequently makes the difference in my ability to communicate effectively, resolve conflicts, negotiate issues,and maintain rapport with others.
3. Useful, occasionally contributes to my ability to build cooperative effort within the project team and across project bounds, and communicate with others in their own contexts.
4. Not very important, rarely consequential to my ability to manage people.
5. Of no importance, can manage people effectively without it.

11. Do you have any comments relative to this questionnaire?

Questionnaire ASD Survey Control Number 91-372
Expires 1 Aug 91

1. Indicate the number of years experience you have in DoD acquisition:

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2. > 3 to < 8 years
3. 8 years or more

2. Select the response most indicative of the technology involved in your project(s).

1. Experimental--evolutionary... at the frontier of scientific and engineering knowledge... aspects, tools, and techniques have been demonstrated in lab environments or only simulated.

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3. Select the response which best describes the number of credit hours (undergraduate and graduate) you have in subjects which directly contributed to your technical competency:

1. 25 credit hours or less
2. > 25 but < 50 credit hours
3. 50 to 90 credit hours
4. > 90 but < 120 credit hours
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4. Not very important, rarely consequential to my ability to manage
5. Of no importance, can manage effectively without it.

6. Based on your experience, use a 1 to 6 scale (1-most consequential, 6-least consequential) and RANK the attributes/skills which follow to indicate the impact of each on overall project success:

_____ Team building skills... fostering commitment, coaching
_____ Leadership... influencing others, providing direction, vision, etc.
_____ Coping skills... patience, persistence, flexibility
_____ Technical competence... ability to apply technical experience and knowledge, etc.
_____ Abilities in communication ... listening, persuading, etc.
_____ Organizational skills... planning, goal-setting, analyzing, etc.

7. Recall the PHASES in the Acquisition Process (as outlined in DoD Directive 5000.1). Based upon your experience, RANK the acquisition phases below in the order which indicates when technical competence is most important. Use a 1 to 5 scale (1-technical competence is MOST important during this phase, 5- technical competence is LEAST important during this phase), and use each rank only ONCE. AFTER RANK ORDERING THE PHASES, place a check mark (√) beside any phase for which you may have inadequate experience.

_____ Concept Exploration & Definition
_____ Demonstration & Validation
_____ Engineering & Manufacturing Development
_____ Production & Deployment
_____ Operations & Support

8. Consider the factors which contribute to your technical competence. Using a 1 to 7 scale (1-most important, 7-least important), RANK the 7 items which follow to indicate the relative importance of each in developing your technical competency. Use each RANK only ONCE.

_____ On-the-job training
_____ Your aptitude for asking questions and soliciting information on technical issues.
_____ Accredited undergraduate and graduate engineering degree programs.
_____ Operational experience
_____ Mentor- working/apprenticing under an authority/expert in acquisition management
_____ Other educational endeavors (e.g., additional college courses, seminars, etc.)
_____ Professional readings (e.g., journals like IEEE, periodicals, manuals, etc.)

9. Based on your experience, use a 1 to 6 scale (1-use the most, 6-use the least) and RANK the attributes/skills which follow to indicate the relative amount of time you rely on them as an acquisition manager. Use each RANK only ONCE.

_____ Leadership... influencing others, providing direction, vision, etc.
_____ Technical competence... ability to apply technical experience and knowledge, etc.
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4. Not very important, rarely consequential to my ability to manage people.
5. Of no importance, can manage people effectively without it.

11. Do you have any comments relative to this questionnaire?

Appendix C: Survey Data

	SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WC	WA	WC	WT	WL	IC	AF
	SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WC	WA	WC	WT	WL	IC	AF
1	2	2	3	2	5	1	1	2	4	1	6	3	5	1	2	3	4	5	7	6	3	5	1	2	4	5	1	3	6	4	2	1	29
2	3	1	3	2	4	1	2	3	5	4	6	1	2	4	3	1	2	5	7	6	2	3	1	4	5	5	1	2	6	3	4	2	29
3	5	1	3	2	5	1	1	3	4	1	6	2	5	3	2	1	4	5	4	5	2	3	1	7	6	5	3	4	6	1	2	2	29
4	6	2	3	3	4	2	2	4	3	5	6	1	2	1	2	3	4	5	4	6	5	3	7	2	1	2	4	3	6	5	1	3	29
5	7	1	3	2	1	1	2	4	2	3	6	1	5	5	3	1	2	4	5	6	4	1	7	2	3	5	6	2	4	3	1	2	29
6	8	2	3	2	5	2	2	4	3	5	6	1	2	3	2	1	4	5	7	6	5	1	2	3	4	5	4	3	1	6	2	3	29
7	9	1	3	2	3	2	3	2	3	6	5	1	4	3	1	2	4	5	6	7	2	5	1	4	3	2	3	4	5	6	1	3	29
8	11	1	3	2	5	2	2	6	2	4	5	1	3	3	1	2	4	5	6	5	2	4	3	7	1	3	4	2	5	6	1	3	29
9	13	1	3	2	4	1	3	2	3	5	6	1	4	3	1	2	4	5	7	3	2	6	1	4	5	4	5	2	6	5	1	3	29
10	14	2	2	2	2	1	1							1	3	2	4	5	3	6	4	5	1	7	2							2	29
11	15	1	3	2	4	1	2	2	1	3	4	6	5	1	2	3	4	5	5	6	1	7	2	4	3	5	2	1	4	3	6	4	29
12	16	2	3	3	4	2	3	5	3	6	4	1	2	1	2	3	4	5	7	6	3	1	5	4	2	2	5	3	4	6	1		29
13	18	2	3	2	1	1	2	5	3	2	6	1	4	2	1	3	4	5	7	6	4	3	5	1	2	3	5	1	6	4	2	3	11
14	19	1	2	2	4	3	1	3	1	2	6	4	5	1	2	3	4	5	7	6	4	1	5	2	3	5	3	1	6	2	4	2	11
15	21	1	3	3	3	2	2	3	4	6	5	1	2	3	2	1	4	5	5	2	6	7	1	3	4	4	2	3	5	6	1	3	11
16	22	2	2	2	5	1	2	1	3	2	5	4	6	3	1	2	4	5	7	6	1	5	4	2	3	6	1	3	5	2	4	2	11
17	23	1	2	2	1	2	2	2	5	6	4	1	3	1	2	3	4	5	1	2	6	4	3	5	7	5	2	1	3	6	4	3	11
18	24	2	2	3	4	2	1	4	2	6	5	1	3	1	2	3	4	5	4	3	5	7	6	1	2	5	6	1	2	3	4	3	11
19	27	2	1	3	3	2	3	3	4	6	5	2	1	2	1	3	4	5	5	6	1	3	7	4	2	1	4	3	5	6	2	3	11
20	30	1	3	1	2	2	2	3	5	4	6	2	1	3	1	2	5	4	5	6	2	3	4	1	7	3	5	1	6	4	2	2	11
21	31	2	1	1	2	2	2	1	4	3	6	2	5	5	1	2	4	3	7	4	3	5	2	6	1	5	1	3	6	4	2	3	11
22	32	1	1	2	5	2	2	4	2	3	6	1	5	4	1	2	3	5	7	5	3	1	6	4	2	5	2	3	6	4	1	2	11
23	33	2	3	2	3	1	3	4	2	5	6	1	3	1	3	2	4	5	4	6	5	7	3	1	2	6	1	2	3	5	4	2	11
24	34	1	3	2	4	2	2	4	3	1	6	5	2	1	2	3	4	5	7	6	4	5	1	3	2	2	6	3	4	1	5	2	11
25	35	2	3	2	3	2	.2	4	2	3	6	1	5	5	3	1	2	4	7	6	4	3	5	1	2	5	4	2	6	3	1	2	11
26	36	1	3	2	4	2	1	2	4	1	6	3	5	3	1	2	4	5	4	3	5	7	1	2	6	6	1	5	4	2	3	2	11
27	37	2	3	2	5	2	2	4	2	3	6	1	5	3	2	1	4	5	7	6	5	3	1	4	2	4	5	2	6	3	1	3	11
28	38	1	2	2	3	2	4	1	2	5	4	3	6	4	2	1	3	5	7	2	1	6	5	4	3	6	1	2	4	5	3	4	11
29	40	2	3	2	5	1	3	3	6	5	4	1	2	1	2	3	4	5	5	3	4	6	7	2	1	2	4	5	3	6	1		11
30	41	2	2	1	2	2	3	3	5	4	6	2	1	3	1	2	4	5	6	4	5	1	3	2	7	1	2	5	6	3	4	2	11
31	42	1	1	2	1	2	3	1	4	6	5	3	2	1	2	3	4	5	4	6	3	5	7	1	2	3	2	4	5	6	1	4	11
32	44	1	3	1	4	1	3	5	2	6	4	1	3	3	2	1	4	5	7	3	6	5	1	2	4	3	4	2	5	6	1	3	11
33	46	1	3	2	1	1	2	2	4	5	6	1	3	2	1	3	4	5	2	4	7	5	6	1	3	4	3	2	6	5	1	3	11
34	49	2	3	2	3	2	3	3	2	6	5	1	4	2	1	3	4	5	4	5	3	6	7	2	1	3	2	4	5	6	1	3	11
35	50	1	3	3	3	1	3	5	2	4	6	1	3	4	2	1	3	5	6	5	1	7	4	3	2	3	5	2	6	4	1	3	16
36	51	2	3	2	2	2	3	5	1	3	4	2	6	1	2	4	3	5	6	5	4	7	2	3	1	6	5	1	4	3	2	3	16
37	52	1	3	3	2	2	2	1	2	4	3	5	6	4	1	2	3	5	7	5	2	4	3	1	6	2	4	1	5	6	3	4	16
38	53	2	3	2	4	2	2	3	2	4	5	1	6	3	1	2	4	5	7	6	2	4	5	1	3	6	3	2	4	5	1	3	16
39	54	1	3	3	2	2	2	1	5	4	3	6	2	2	1	3	4	5	5	6	7	1	2	4	3	5	6	2	1	3	4	3	16
40	55	2	3	3	2	1	2	2	3	4	6	1	5	3	1	2	4	5	7	1	5	3	4	6	2	6	3	2	5	4	1	3	16
41	57	2	3	2	5	2	3	4	2	5	3	1	6	1	2	3	4	5	6	7	1	4	5	3	2	6	4	3	2	5	1	3	16
42	60	1	3	2	1	2	4	1	3	6	2	4	5	1	3	2	5	4	4	3	5	6	7	1	2	5	2	1	4	6	3	3	16
43	63	2	2	2	3	3	1	3	2	5	6	1	4	5	1	2	3	4	5	7	6	4	1	2	3	3	4	2	6	5	1	1	16
44	64	1	3	1	5	1	2	5	4	6	3	1	2	3	1	2	4	5	7	5	6	3	1	2	4	4	5	2	6	3	1	3	16
45	65	2	2	2	1	1	2	2	3	5	6	1	4	1	2	3	4	5	3	6	5	4	7	1	2	4	2	3	6	5	1	3	16
46	67	1	3	2	5	2	2	5	2	3	6	1	4	3	2	1	4	5	5	4	3	6	1	2	7	4	5	2	6	3	1	2	16
47	69	1	3	2	1	3	3	5	3	6	4	1	2	2	1	3	4	5	7	6	1	2	3	4	5	3	4	1	5	6	2	4	16
48	70	2	3	2	5	1	2	5	4	3	6	2	1	2	1	3	4	5	5	7	6	4	3	2	1	3	2	1	6	5	4	2	16
49	72	2	3	2	5	1	1	5	4	3	6	1	2	3	2	1	4	5	7	6	4	5	1	2	3	2	5	3	6	4	1	2	16
50	73	1	3	2	4	1	2	4	1	3	5	2	6	2	1	3	4	5	6	5	7	2	1	3	4	3	6	1	5	4	2	1	16
51	74	2	3	1	4	2	3	5	2	4	6	1	3	3	2	1	4	5	7	2	5	6	1	4	3	3	5	2	6	4	1	3	16

	SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WC	WA	WC	WT	WL	IC	AF
52	79	1	3	2	5	2	2	5	6	4	2	1	3	1	2	3	4	5	7	6	2	3	5	4	1	3	5	6	2	4	1	2	16
53	80	2	3	2	5	2	3	6	3	4	5	1	2	3	2	1	4	5	7	6	5	2	4	1	3	2	6	3	5	4	1	3	16
54	84	2	3	2	1	1	4	4	3	6	5	1	2	1	3	2	4	5	7	3	5	4	6	2	1	1	2	4	5	6	3	4	16
55	91	1	3	2	5	2	2	2	3	5	4	1	6	3	2	1	4	5	5	6	4	7	2	1	3	4	5	3	2	6	1	3	16
56	92	2	2	2	2	2	3	3	2	1	6	4	5	1	3	2	4	5	5	4	3	2	6	7	1	5	2	1	3	4	6	2	16
57	94	2	3	2	4	1	2	5	4	2	6	3	1	2	1	3	5	4	6	7	1	3	5	4	2	1	5	4	6	2	3	2	16
58	96	2	3	2	5	2	3	6	2	5	1	4	3	2	1	3	4	5	7	6	5	4	2	1	3	4	5	2	1	6	3	4	16
59	97	1	3	2	3	2	3	4	2	6	5	1	3	1	2	3	5	4	5	2	7	6	1	3	4	3	4	2	5	6	1	3	16
60	99	1	2	3	3	3	1	6	3	4	5	1	2	1	2	3	4	5	6	5	2	7	4	1	3	3	4	2	1	6	5	2	16
61	102	2	3		5	2	2	1	4	5	6	3	2	1	2	3	4	5	6	4	5	7	1	3	2	1	4	5	6	3	2	2	16
62	104	2	3	1	3	2	1	6	4	3	5	1	2	1	2	3	4	5	7	6	2	4	3	5	1	5	6	3	4	2	1	2	16
63	105	1	2	2	4	1	1	4	3	2	6	1	5	5	1	2	3	4	7	6	3	1	5	2	4	2	5	4	6	3	1	1	16
64	106	2	3	2	5	2	2	1	4	5	6	3	2	3	1	2	4	5	7	4	3	6	1	5	2	2	1	4	6	5	3	2	16
65	107	1	3	2	4	2	3	6	3	5	4	1	2	1	2	3	4	5	7	3	4	2	5	6	1	2	5	3	4	6	1	3	16
66	108	2	3	2	5	1	1	6	3	5	1	2	4	2	1	3	4	5	7	6	3	5	4	2	1	4	5	2	1	6	3	2	16
67	109	1	3	2	3	2	2	5	2	6	4	1	3	3	1	2	4	5	5	6	3	4	7	1	2	3	5	2	4	6	1	3	16
68	112	2	2	3	5	3	2	1	5	3	6	4	2	4	1	2	3	5	7	6	2	1	3	5	4	2	1	5	6	3	4	3	16
69	114	1	2	2	2	1	2	5	1	4	6	3	2	2	1	3	4	5	6	5	3	7	1	2	4	2	5	1	6	4	3	3	16
70	116	2	3	2	3	2	3	4	2	5	3	1	6	1	2	3	4	5	7	6	5	3	2	1	4	6	3	2	4	5	1	3	16
71	117	1	3	2	4	1	2	5	6	3	4	1	2	4	2	1	3	5	6	7	3	5	1	2	4	2	6	5	4	3	1	3	16
72	118	2	3	2	3	2	3	3	2	6	5	1	4	3	2	1	4	5	6	7	5	2	1	4	3	3	4	2	5	6	1	2	16
73	119	1	3	2	2	2	3	6	2	5	3	1	4	2	1	3	4	5	7	6	1	5	3	4	2	4	6	1	3	5	2	3	16
74	120	2	2	2	2	2	2	3	2	4	5	1	6	3	1	2	5	4	6	1	5	7	2	3	4	6	5	1	4	2	3	2	16
75	121	1	3	1	4	1	2	5	3	4	6	1	2	3	1	2	4	5	4	6	1	7	3	2	5	2	5	3	6	4	1	2	16
76	122	2	3	1	5	2	3	3	4	6	5	1	2	3	2	1	4	5	6	5	3	7	4	1	2	2	5	4	1	6	3	3	16
77	124	2	1	2	5	1	2	4	3	2	6	1	5	3	1	2	4	5	5	6	1	7	4	3	2	6	1	2	5	4	3	3	21
78	125	1	1	1	3	2	2	6	2	5	4	1	3	2	1	3	4	5	3	2	6	7	1	4	5	3	6	2	4	5	1	1	21
79	126	2	1	2	5	2	2	1	3	2	6	5	4	1	2	3	4	5	5	6	4	7	1	3	2	4	1	3	6	2	5	3	21
80	127	1	1	1	2	1	2	3	4	2	5	1	6	3	1	2	4	5	6	4	2	5	7	3	1	6	1	2	4	3	5	2	21
81	128	2	1	3	5	2	2	4	3	2	6	1	5	1	3	2	4	5	6	3	2	1	7	4	5	4	3	2	5	6	1	1	21
82	130	2	1	3	4	2	2	1	5	3	4	2	6	1	3	2	5	4	7	6	5	1	2	3	4	4	6	3	2	1	5	3	21
83	132	2	1	2	3	2	4	2	1	5	6	4	3	1	2	3	4	5	6	1	4	5	7	2	3	4	5	1	3	6	2	3	21
84	134	2	1	2	3	3	4	4	2	6	5	1	3	1	2	3	4	5	2	3	5	4	7	6	1	5	3	2	4	6	1	4	21
85	136	2	2	2	5	1	1	2	5	3	6	1	4	3	1	[illegible]	5	4	5	6	4	7	2	3	1	4	5	3	6	2	1	2	21
86	137	1	1	3	2	2	2	4	2	3	6	5	1	1	3	[illegible]	4	5	6	7	2	3	5	4	1	2	3	4	5	1	6	3	21
87	138	2	1	2	5	2	3	1	6	4	2	3	5	5	2	1	3	4	7	4	6	2	3	1	5	5	1	4	2	6	3	2	21
88	139	1	2	1	1	2	2	5	2	1	3	4	6	2	1	3	4	5	7	3	5	6	1	4	2	6	4	1	3	2	5	1	21
89	140	2	1	2	4	2	2	2	3	5	6	1	4	1	2	3	5	4	7	6	4	5	2	3	1	6	1	3	5	2	4	3	21
90	143	1	2	2	4	2	2	1	4	3	5	2	6	2	1	3	4	5	7	5	1	6	3	4	2	6	1	4	5	2	3	2	21
91	145	1	1	2	5	2	2	1	2	3	5	4	6	3	4	1	2	5	6	4	5	2	1	3	7	6	1	2	5	3	4	2	21
92	146	2	1	3	1	2	3	5	2	4	6	1	3	3	2	1	5	4	4	7	2	6	5	3	1	2	5	1	6	4	3	2	21
93	147	1	1	2	4	2	4	1	2	6	4	3	5	2	1	3	4	5	6	7	4	1	3	2	5	6	2	3	1	5	4	2	21
94	151	2	2	3	1	3	2	1	5	6	4	2	3	1	2	3	5	4	4	7	3	6	5	1	2	5	1	4	6	3	2	2	24
95	154	1	2	2	3	2	3	2	4	6	5	3	1	3	2	1	5	4	7	3	2	1	5	4	6	1	2	4	5	6	3	3	24
96	155	2	1	2	5	2	3	1	2	4	3	5	6	1	2	3	4	5	7	5	3	6	2	4	1	6	1	2	3	4	5	3	24
97	156	1	2	2	3	2	1	1	3	4	6	2	5	1	2	3	4	5	7	6	2	4	1	3	5	5	1	2	6	4	3	2	24
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99	159	2	2	3	1	2	5	2	3	6	5	1	4													4	2	3	5	6	1	5	24
100	161	2	2	2	4	1	1	2	4	5	6	3	1	5	1	2	3	4	5	6	4	7	1	3	2	1	2	4	6	5	3	3	24
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109	170	2	2	3	5	1	1	2	6	3	5	1	4	4	1	2	3	5	7	3	2	5	6	4	1	6	1	2	4	5	3	2	24
110	171	1	1	2	3	3	1	1	4	2	5	3	6	4	2	1	3	5	7	5	4	6	3	1	2	6	1	4	5	2	3	2	24
111	173	2	1	2	1	1	3	2	3	6	5	1	4	1	2	3	4	5	6	5	4	2	7	6	1	3	4	1	2	6	5	3	24
112	174	1	1	3	3	2	1	2	3	5	6	1	4	1	2	3	4	5	5	2	6	1	7	3	4	4	2	3	6	5	1	2	24
113	175	1	2	2	3	2	3	2	1	6	4	5	3	3	1	2	4	5	7	5	2	6	3	1	4	2	3	1	4	6	5	3	24
114	176	2	1	2	2	3	3	6	3	5	4	2	1	3	1	2	4	5	7	5	4	1	6	3	2	3	6	2	1	5	4	3	24
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120	185	1	2	2	5	2	3	3	1	6	5	2	4	3	2	1	4	5	6	5	4	3	7	1	2	5	3	1	2	6	4	2	24
121	187	1	2	2	3	2	2	1	2	4	5	3	6	4	3	1	2	5	6	3	4	5	1	2	7	6	1	2	5	3	4	2	24
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123	190	2	1	2	1	2	2	6	5	3	4	1	2	1	3	2	4	5	7	6	3	5	2	1	4	6	4	2	5	3	1	3	24
124	194	2	2	2	1	2	2	1	2	3	6	5	4	3	1	2	4	5	3	6	5	4	7	1	2	6	2	1	5	3	4	3	24
125	195	1	1	2	3	2	2	1	3	2	5	4	6	3	1	2	4	5	6	3	2	5	7	1	4	4	1	2	5	3	6	3	24
126	196	2	2	2	3	3	1	3	5	2	4	1	6	1	3	2	4	5	7	6	5	2	3	4	1	6	3	5	4	1	2	2	24
127	197	1	2	2	2	2	2	1	5	6	3	2	4	2	1	3	4	5	7	5	6	4	1	3	2	5	1	2	3	6	4	2	24
128	198	2	1	2	1	2	3	1	3	2	5	4	6	1	3	2	5	4	7	6	1	4	5	2	3	4	1	2	5	3	6	2	24
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141	222	1	1	2	3	2	3	6	1	3	4	5	2	5	4	1	2	3	7	6	2	5	4	1	3	6	3	1	5	4	2	3	24
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144	227	2	2	3	4	2	3	1	3	5	6	4	2	1	2	3	4	5	2	6	7	5	1	3	4	2	1	3	6	5	4	4	24
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	SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WO	WA	WC	WT	WL	IC	AF
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162	252	1	3	2	5	2	2	6	1	5	4	2	3	2	1	3	5	4	7	1	4	3	2	5	6	6	2	1	4	5	3	2	24
163	253	2	1	3	2	2	3	1	3	6	2	4	5	1	2	3	5	4	7	6	3	5	4	2	1	6	1	5	2	4	3	4	24
164	255	2	2	3	3	2	1	4	1	3	6	5	2	1	2	4	5	3	6	5	2	7	3	4	1	2	3	1	6	4	5	2	24
165	256	1	2	2	3	1	2	1	5	2	6	3	4	1	2	3	4	5	7	6	4	3	5	2	1	4	1	2	6	3	5	2	24
166	262	1	2	2	5	2	3	3	2	1	6	4	5	3	4	1	5	2	7	3	5	2	4	6	1	2	6	1	5	3	4	3	24
167	264	1	2	2	3	2	2	1	5	3	2	4	6	4	2	1	3	5	6	3	5	7	4	1	2	6	3	1	2	4	5	2	24
168	265	2	2	1	3	2	2	4	3	5	6	1	2	1	3	2	4	5	6	5	4	7	3	1	2	2	4	3	6	5	1	2	24
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170	268	1	2	2	4	2	3	3	2	6	1	4	5	1	2	3	4	5	5	7	4	6	2	1	3	6	5	4	1	3	2	2	24
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187	297	2	2	2	1	2	3	5	1	6	2	3	4	5	1	2	3	4	6	5	3	2	7	4	1	4	5	3	1	6	2	3	24
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189	299	2	2	3	5	3	1	4	1	2	6	2	5	2	1	3	4	5	4	2	7	6	1	3	5	3	6	2	4	5	1	1	24
190	302	1	2	2	4	1	1	2	1	4	6	3	5	1	2	3	4	5	6	7	1	3	2	4	5	6	2	1	5	3	4	2	24
191	303	2	2	2	4	3	3	6	1	5	3	2	4	1	2	3	4	5	5	4	3	7	1	2	6	4	5	1	2	6	3	4	24
192	304	1	2	2	5	2	2	3	5	4	6	1	2	1	2	3	4	5	6	5	2	7	4	1	3	2	5	3	4	6	1	2	24
193	306	1	2	2	1	3	2	4	1	5	2	3	6	4	1	2	3	5	4	6	5	7	1	3	2	6	2	3	1	4	5	3	24
194	307	2	3	2	5	2	2	5	2	6	4	1	3	3	1	2	4	5	3	2	5	7	1	4	6	3	5	2	4	6	1	2	24
195	308	1	2	2	3	2	3	2	1	5	6	4	3	3	1	2	4	5	6	5	3	7	2	4	1	3	2	1	6	5	4	3	24
196	309	2	1	2	1	2	3	1	2	6	5	4	3	3	4	1	2	5	7	6	4	3	5	2	1	4	1	2	3	6	5	3	24
197	310	1	1	3	1	1	3	1	3	2	4	5	6	3	2	1	4	5	7	5	6	1	6	4	2	6	1	2	3	4	5	2	24
198	311	2	2	3	3	2	2	3	2	6	5	1	4	1	2	3	4	5	7	6	3	2	4	1	5	4	3	2	5	6	1	2	16
199	312	1	2	2	1	2	2	2	3	5	6	4	1	3	1	2	4	5	7	2	6	1	5	3	4	3	2	1	6	4	5	3	16
200	313	2	2	2	2	2	2	1	4	5	6	3	2	1	2	3	4	5	6	7	5	3	2	1	4	3	1	2	6	5	4	3	24
201	314	1	2	2	5	1	3	4	5	6	3	1	2	2	1	3	4	5	6	5	3	1	7	2	4	4	6	3	2	5	1	3	11
202	318	1	3	2	1	2	2	1	5	2	6	4	3	5	4	2	1	3	6	5	3	4	7	2	1	2	1	3	6	5	4	2	16
203	320	1	2	2	5	2	3	1	2	4	3	5	6	3	1	2	4	5	7	5	2	1	3	6	4	6	1	4	3	2	5	3	16
204	321	2	3	2	2	1	3	1	4	6	5	3	2	1	2	3	4	5	5	6	3	1	7	4	2	2	1	3	5	6	4	4	21
205	322	1	2	2	2	1	3	3	1	6	5	2	4	3	1	2	4	5	7	5	4	1	6	2	3	4	2	1	5	6	3	3	16
206	325	2	1	1	1	2	3	2	4	1	6	3	5	1	2	3	4	5	7	4	5	1	3	6	2	3	4	1	5	6	2	4	16
207	326	1	2	1	5	1	3	1	5	3	2	4	6	1	2	3	4	5	7	5	4	1	3	6	2	6	1	4	2	3	5	3	11
208	328	1	2	1	5	2	1	5	1	2	6	3	4	1	2	3	4	5	4	6	7	3	2	1	5	4	5	1	6	2	3	2	11
209	331	2	3	1	5	1	1	4	2	6	5	1	3	2	1	3	4	5	6	7	1	3	2	5	4	3	4	2	5	6	1	4	11
210	332	1	3	1	5	2	2	3	1	5	2	4	6	2	1	4	5	3	7	5	4	3	6	1	2	3	1	5	2	4	6	3	16

	SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WC	WA	WC	WT	WL	IC	AF
211	333	2	3	1	5	3	1	4	3	2	5	1	6	1	2	3	4	5	5	6	2	7	1	4	3	6	4	3	5	2	1	2	16
212	334	1	3	1	4	1	1	3	2	4	6	1	5	2	1	3	4	5	4	2	6	7	1	5	3	2	3	5	1	4	6	1	16
213	335	1	2	1	5	2	3	2	5	3	6	1	4	4	1	2	3	5	7	2	4	6	1	3	5	5	2	3	6	4	1	3	16
214	336	2	3	1	1	2	2	3	4	5	6	1	2	1	2	3	4	5	7	4	6	2	1	5	3	2	3	4	6	5	1	2	16
215	337	1	2	1	4	1	2	3	2	4	6	1	5	2	1	3	4	5	6	5	7	4	2	1	3	6	4	1	2	3	5	2	16
216	338	1	1	1	4	2	2	6	2	4	5	1	3	2	3	1	4	5	7	5	1	3	6	4	2	5	4	1	2	3	6	2	21
217	339	2	2	2	2	1	2	5	6	3	2	1	4	4	1	2	3	5	7	6	4	5	3	1	2	4	5	6	2	3	1	2	21
218	341	2	3	2	3	1	2	6	2	3	5	4	1	3	2	1	4	5	6	5	4	7	2	3	1	1	6	2	5	3	4	2	24
219	342	1	3	1	1	2	2	3	1	2	6	4	5	3	2	1	4	5	6	2	1	4	5	3	7	6	2	1	5	3	4	2	24
220	343	2	2	1	3	2	1	4	2	3	6	5	1	2	1	3	4	5	7	5	3	6	4	1	2	1	3	4	5	6	2	2	24
221	350	1	2	1	3	1	2	2	3	1	6	4	5	1	2	3	4	5	6	3	4	7	2	5	1	5	2	3	4	1	6	2	24
222	351	2	2	2	3	3	3	2	3	4	6	1	5	1	2	3	4	5	6	4	1	3	5	7	2	4	5	1	2	6	3	3	24
223	352	2	2	1	3	1	2	6	1	5	4	3	2	1	2	3	4	5	7	6	5	1	4	3	2	3	6	1	5	4	2	2	24
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225	354	1	2	1	5	2	2	2	1	4	5	3	6	4	2	1	3	5	6	4	5	7	3	2	1	6	3	2	5	4	1	2	24
226	355	2	1	2	2	3	2	1	4	2	6	5	3	1	2	3	4	5	7	5	4	1	6	2	3	6	1	4	5	2	3	2	24
227	356	2	2	2	2	3	2	1	2	4	6	5	3	2	3	1	4	5	6	5	3	7	4	1	2	3	1	2	5	6	4	3	24
228	357	1	3	2	4	2	3	6	2	4	5	1	3	3	1	2	4	5	6	7	3	5	4	1	2	5	6	2	3	4	1	4	24

SCN	SV	EX	PT	HT	TT	IT	CO	CA	CT	CC	CL	CB	AC	AD	AE	AP	AO	FP	FO	FM	FE	FA	FY	FT	WB	WO	WA	WC	WT	WL	IC	AF

Data Code Key

SCN: Survey Control Number
SV: Survey Version Number
EX: Experience Level
PT: Project Technology Level
HT: Category Indicating Level of Technical Academic Training
TT: Category Indicating Caliber of Technical Project Team
IT: Perceived Importance of Technical Competence

Ranks of Skills Relative to Importance to Project Success
CO: Organizational Skills
CA: Abilities in Communication
CT: Technical Competence
CC: Coping Skills
CL: Leadership
CB: Team Building

Ranks of Technical Competence Relative to Acquisition Phase
AC: Concept Exploration & Definition
AD: Demonstration & Validation
AE: Engineering & Manufacturing Development
AP: Production & Deployment
AO: Operations & Support

Ranks of Various Means of Developing Technical Competence
FP: Professional Readings
FO: Other Educational Endeavors (e.g., PCE courses)
FM: Mentor/Apprenticing
FE: Operational Experience
FA: Accredited Engineering Degrees
FY: Aptitude for Acquiring and Understanding Technical Information
FT: On-the-Job Training

Ranks of Skills Based on Extent of Use in Project Activities
WB: Team Building
WO: Organizational Skills
WA: Abilities in Communication
WC: Coping Skills
WT: Technical Competence
WL: Leadership

IC: Perceived Importance of Technical Competence to Interpersonal Skills
AF: Air Force Specialty Code Index for Respondent

Appendix D: Statistical Test Results

Hypothesis #1: Table 26 reports the descriptive statistics used to assess this hypothesis.

TABLE 26

Descriptive Statistics for Hypothesis #1

X_1: Technical Competency Importance

Bar:	From: (≥)	To: (<)	Count:	Percent:	
1	1	2	41	17.982%	
2	2	3	100	43.86%	-Mode
3	3	4	78	34.211%	
4	4	5	8	3.509%	
5	5	6	1	.439%	

X_1: Technical Competency Importance

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
2.246	.803	.053	.644	35.743	228
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
1	5	4	512	1296	0
# < 10th %:	**10th %:**	**25th %:**	**50th %:**	**75th %:**	**90th %:**
0	1	2	2	3	3
# > 90th %:	**Mode:**	**Kurtosis:**	**Skewness:**		
9	2	-.253	.144		

Hypothesis #2: The Kruskal-Wallis was used to test whether differences existed in the perceived importance of technical competence among different populations of acquisition managers as grouped by experience. The following statements represent the null and alternate hypotheses as stated for the test:

- H_0: The three groups of acquisition managers (categorized by experience) are equivalent in perceived importance of technical competence
- H_a: Some groups of acquisition managers (categorized by experience) tend to perceive technical competence as more important compared to the others.

Table 27 describes the statistical test results for this hypothesis.

TABLE 27

Results of Kruskal-Wallis for Hypothesis #2

Kruskal-Wallis X_1: Acquisition Experience Y_1: Technical Competency Importance

DF	2	
# Groups	3	
# Cases	228	
H	.14	p = .9323
H corrected for ties	.161	p = .9226
# tied groups	4	

Kruskal-Wallis X_1: Acquisition Experience Y_1: Technical Competency Importance

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	48	5648	117.667
Group 2	92	10459	113.685
Group 3	88	9999	113.625

Hypothesis #3. The following statements represent the null and alternate hypotheses for the test of Hypothesis #3:

- H_0: The three groups of acquisition managers (organized by experience) are equivalent in perceived importance of technical competence relative to other skills as a function of the extent of use in project activities.
- H_a: Some groups (populations organized by experience) tend to perceive technical competence as more important relative to other skills in terms of the extent of use in project activities.

Although the test manifested a relatively low p-value (p = .1775), the null could not be rejected. The three populations of acquisition managers (grouped by experience) are essentially equivalent in perceived importance

of technical competence relative to the extent of use among other skills in project activities. It is interesting to note that while there is not a statistically significant difference between groups, the distribution of responses, Figure 22, and the mean ranks in Table 28 suggest that acquisition managers with less experience rated technical competence as more important.

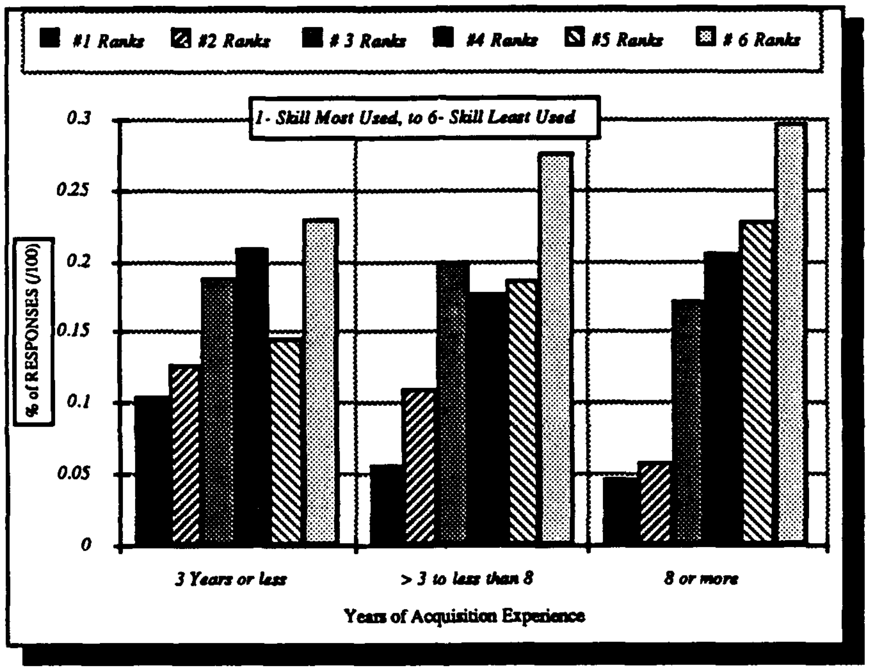

Figure 22. Rankings of Technical Competence Relative to Use Among Other Skills in Project Activities by Experience Level

TABLE 28

Mean Ranks of Technical Competence Relative to Use Among Other Skills in Project Activities as a Function of Acquisition Experience

Population: Acquisition managers with...	Mean Rank of Technical Competence
3 years or less experience...	3.85
> than 3 to less than 8 years experience...	4.15
8 or more years of acquisition experience	4.40

Table 29 describes the statistical test results for this hypothesis.

TABLE 29

Results of Kruskal-Wallis for Hypothesis #3

Kruskal-Wallis X_1: Acquisition Experience Y_1: Tech Comp in Project Activities

DF	2	
# Groups	3	
# Cases	227	
H	3.312	p = .1909
H corrected for ties	3.458	p = .1775
# tied groups	6	

Kruskal-Wallis X_1: Acquisition Experience Y_1: Tech Comp in Project Activities

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	48	4857	101.188
Group 2	91	10248.5	112.621
Group 3	88	10772.5	122.415

Hypothesis #4: Acquisition managers with less experience consider technical competence more consequential to project success relative to other skills.

The Kruskal-Wallis performed for this hypothesis established if the acquisition project managers among different experience levels were identical in terms of the perceived importance of technical competence to project success, relative to other skills. The following statements represent the null and alternate hypotheses for the test of Hypothesis #4:

• H_0: The three populations of acquisition managers (grouped by experience) are equivalent in perceived importance of technical competence to project success relative to other skills.

• H_a: Some populations of acquisition managers (grouped by experience) tend to perceive technical competence as more important to project success relative to other skills.

Figure 23, a graph of the relative frequency of responses for each of the groups, shows further interest and investigation of Hypothesis #4 may be justified.

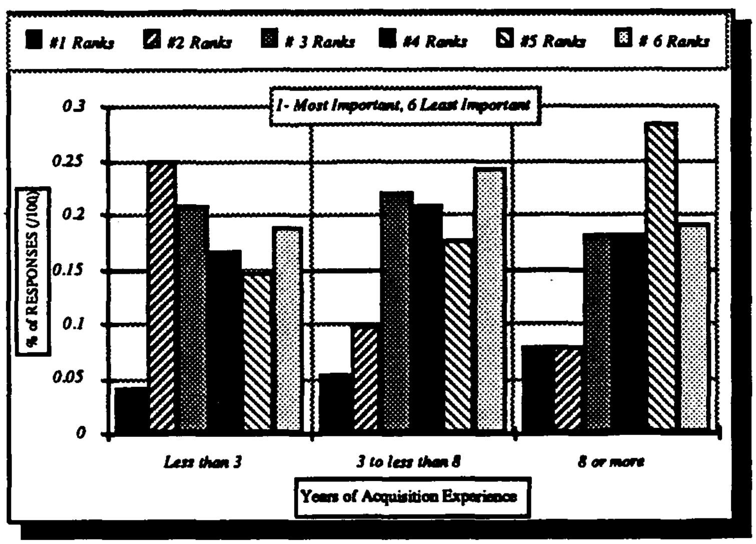

Figure 23. Rankings of the Importance of Technical Competence to Project Success Relative to Other Skills, as a Function of Acquisition Experience: Relative Frequencies.

The relative frequency distributions and mean ranks (Table 30) reveal acquisition managers with less experience tended to rate technical competence as more important to project success relative to other skills. Table 31 reflects the statistical test results for Hypothesis #4.

TABLE 30

Mean Ranks of Technical Competence Relative to Other Skills in Importance to Project Success as a Function of Acquisition Experience

Population Acquisition managers with...	Mean Rank of Technical Competence (1 to 6 Scale, 1- Most Important
less than 3 years experience...	3.44
3 to < 8 years acquisition experience...	4.07
8 or more years of acquisition experience	4.09

TABLE 31

Results of Kruskal-Wallis for Hypothesis #4

Kruskal-Wallis X_1: Acquisition Experience Y_1: Tech Comp and Project Success

DF	2	
# Groups	3	
# Cases	227	
H	2.682	p = .2616
H corrected for ties	2.782	p = .2488
# tied groups	6	

Kruskal-Wallis X_1: Acquisition Experience Y_1: Tech Comp and Project Success

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	48	4812	100.25
Group 2	91	10659	117.132
Group 3	88	10407	118.261

Hypothesis # 5. Acquisition managers with less technically qualified project team members consider technical competence more important (than other acquisition managers).

The Kruskal-Wallis carried out for Hypothesis #5 demonstrated whether the population distribution functions for acquisition managers

with project teams of different technical expertise levels were identical in terms of the perceived importance of technical competence. Table 32 reveals the results of the test. The following statements represent the null and alternate hypotheses in the test of Hypothesis #5:

- H_0: The four populations of acquisition managers (classified by level of project team technical expertise) are equivalent in the perceived importance of technical competence.

- H_a: Some populations (classified by level of project team technical expertise) tend to perceive technical competence as more important based on the technical competence attributed to project team members.

TABLE 32

Results of Kruskal-Wallis for Hypothesis #5

Kruskal-Wallis X_1: Technical Team Y_1: Technical Competency Importance

DF	2	
# Groups	3	
# Cases	228	
H	11.74	p = .0028
H corrected for ties	13.496	p = .0012
# tied groups	4	

Kruskal-Wallis X_1: Technical Team Y_1: Technical Competency Importance

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	67	6506.5	97.112
Group 2	139	17573.5	126.428
Group 3	22	2026	92.091

Hypothesis # 6. Relative to other skills, acquisition project managers with better technically qualified project team members use their technical competence less in project activities.

The Kruskal-Wallis test for Hypothesis #6 examined whether populations of acquisition managers represented by project teams of different technical expertise levels were identical in the perceived importance of technical competence relative to extent of use among other skills in project activities. The following statements represent the null and alternate hypotheses in the test of Hypothesis #6:

- H_0: The groups of acquisition managers (classified by level of project team technical expertise) are equivalent in the perceived importance of technical competence relative to use among other skills in project activities.
- H_a: Some groups of acquisition managers (populations classified by level of project team technical expertise) tend to perceive technical competence as more important relative to other skills in terms of the extent of use in project activities.

(Note , since no subjects rated their project teams poor, the test only involved three populations). The p-value observed and Figure 24, the relative frequency of responses for each of the populations, indicate additional investigation may be worthwhile. Based on mean ranks (Table 33), the acquisition managers with the least or most technically qualified project team members, respectively, appear to perceive technical more important than managers of Reasonably Good teams, relative to use among other skills. Table 34 provides the statistical test results obtained for Hypothesis #6.

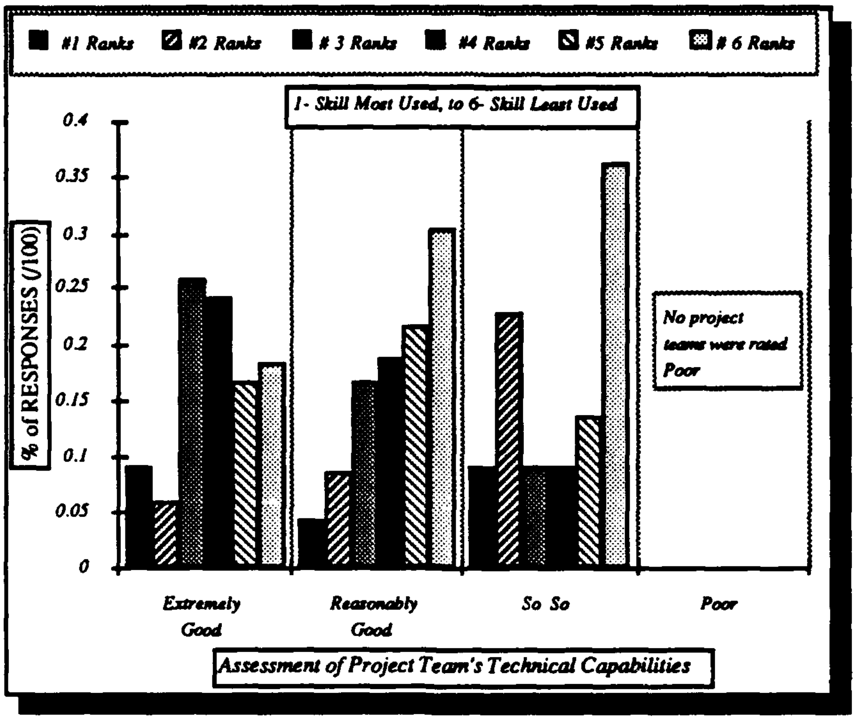

Figure 24. Rankings of Technical Competence Relative to Use Among Other Skills, as a Function of Technical Project Team Capabilities: Relative Frequencies.

TABLE 33

Mean Ranks of Technical Competence Relative to Use Among Other Skills, as a Function of Technical Project Team Capabilities

Population Acquisition managers with...	Mean Rank of Technical Competence
Extremely Good Technical Project Team Members	3.89
Reasonably Good Technical Project Team Members	4.35
So-So Technical Project Team Members	4.05

TABLE 34

Results of Kruskal-Wallis for Hypothesis #6

Kruskal-Wallis X_1: Technical Team Y_1: Tech Comp in Project Activities

DF	2	
# Groups	3	
# Cases	227	
H	4.298	p = .1166
H corrected for ties	4.487	p = .1061
# tied groups	6	

Kruskal-Wallis X_1: Technical Team Y_1: Tech Comp in Project Activities

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	66	6634	100.515
Group 2	139	16789.5	120.788
Group 3	22	2454.5	111.568

Hypothesis # 7. Relative to other skills, Acquisition managers with less technically qualified project team members consider technical competence more consequential to project success.

In Hypothesis #7, the Kruskal-Wallis inspected whether the population distribution functions for acquisition managers with project teams of different technical expertise levels were identical in the perceived importance of technical competence to project success relative to other skills. The following statements represent the.null and alternate hypotheses in the test of Hypothesis #7:

- H_0: The populations of acquisition managers (classified by level of project team technical expertise) are equivalent in the perceived importance of technical competence to project success relative to other skills.

• H_a: Some populations (classified by level of project team technical expertise) tend to perceive technical competence as more important to project success relative to other skills.

(Note, since no subjects rated their project teams poor, the test only represented three groups). Figure 25, a graph of the relative frequency of responses for each of the groupings, also tends to cultivate further interest in exploring Hypothesis #7. Moreover, recognize the p-value reported in Table 35 from the test (p = .169) appears to support additional investigation in this area.

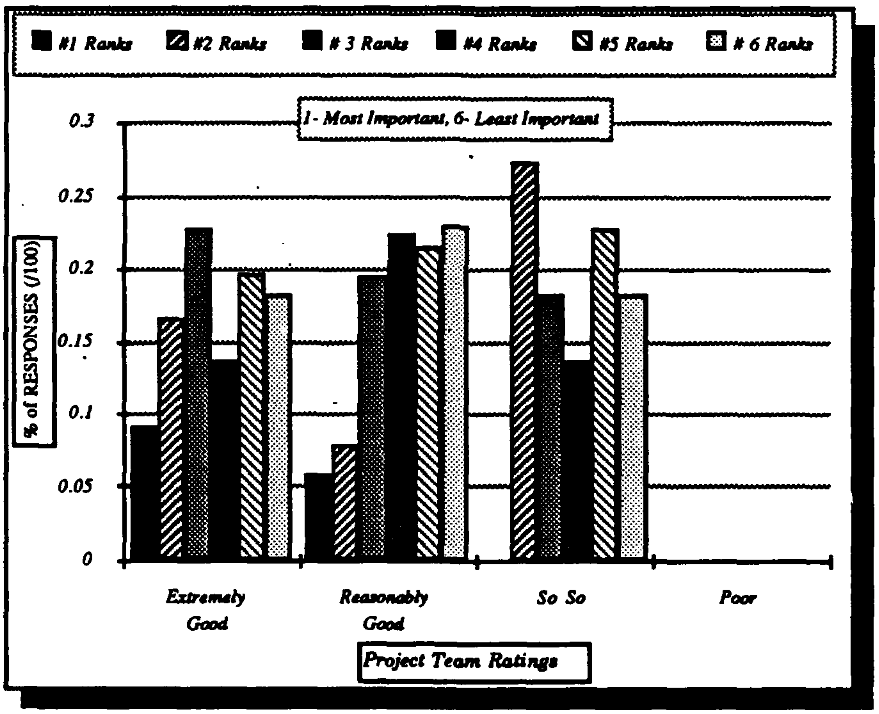

Figure 25. Perceived Importance of Technical Competence to Project Success Relative to Other Skills, as a Function of Technical Project Team Capabilities: Relative Frequencies.

The relative frequency of responses for acquisition managers with the least or most technically qualified project team members, appear to differ from those of *Reasonably Good* technical project teams.

TABLE 35

Results of Kruskal-Wallis for Hypothesis #7

Kruskal-Wallis X_1: Technical Team Y_1: Tech Comp and Project Success

DF	2	
# Groups	3	
# Cases	227	
H	3.418	p = .181
H corrected for ties	3.546	p = .1698
# tied groups	6	

Kruskal-Wallis X_1: Technical Team Y_1: Tech Comp and Project Success

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	66	6794.5	102.947
Group 2	139	16729	120.353
Group 3	22	2354.5	107.023

Hypothesis # 8. Acquisition managers in higher technology projects perceive technical competence more important.

With Hypothesis #8, the Kruskal-Wallis analyzeed whether populations of acquisition managers defined by different levels of project technology were identical in the perceived importance of technical competence. The following represent the null and alternate hypotheses stated for the test of Hypothesis #8:

- H_0: The populations of acquisition managers (classified by level of project technology) are equivalent in the perceived importance of technical competence.

• H_a: Some populations of acquisition project managers (classified by level of project technology) tend to perceive technical competence as more important than others.

Further inquiry may be justified for ˀ ˌothesis #8. Figure 26, the graph of the relative frequency of responses for each of the populations, appears to suggest acquisition managers in experimental technology projects perceive technical competence more important than those in lower level technology projects.

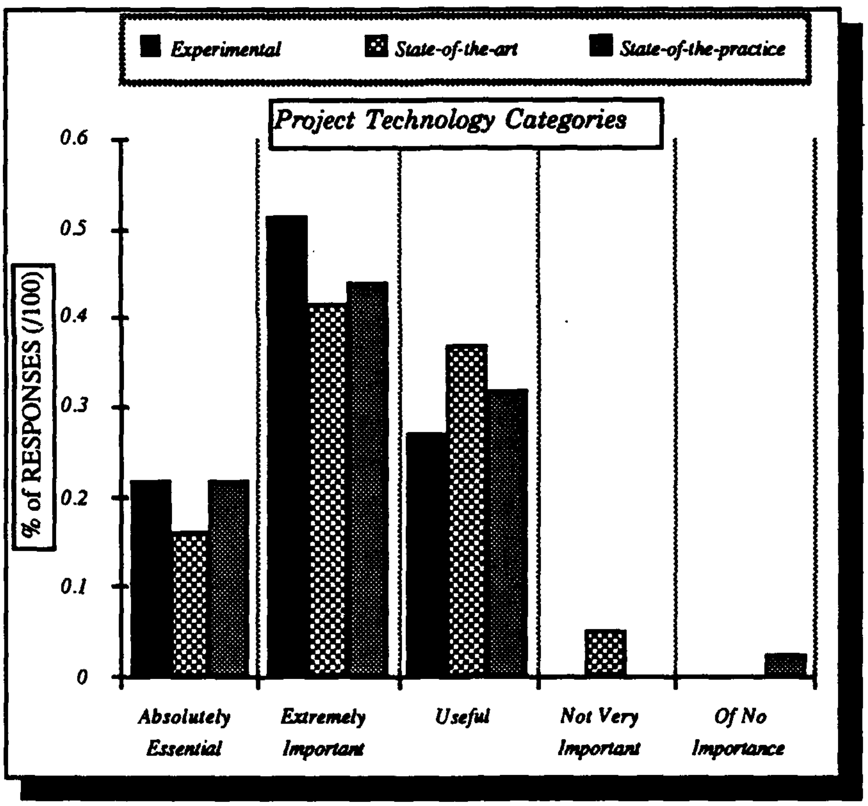

Figure 26. Perceived Importance of Technical Competence as a Function of Project Technology Level: Relative Frequencies.

Table 36 describes the results of the Kruskal-Wallis test performed to examine Hypothesis #8.

TABLE 36

Results of Kruskal-Wallis for Hypothesis #8

Kruskal-Wallis X_1: Project Technology Y_1: Technical Competency Importance

DF	2	
# Groups	3	
# Cases	227	
H	3.225	p = .1994
H corrected for ties	3.705	p = .1569
# tied groups	4	

Kruskal-Wallis X_1: Project Technology Y_1: Technical Competency Importance

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	37	3692	99.784
Group 2	149	17798.5	119.453
Group 3	41	4387.5	107.012

Hypothesis #9. Relative to other skills, acquisition managers in higher technology projects use their technical competence more than those in less technical projects.

The Kruskal-Wallis test of Hypothesis #9 assessed whether populations of acquisition managers defined by different levels of project technology were identical in the perceived importance of technical competence based on extent of use relative to other skills. Table 37 shows the test results. The following represent the null and alternate hypotheses in the test of Hypothesis #9:

- H_0: The populations of acquisition managers (classified by level of project technology) are equivalent in the perceived importance of technical competence based on extent of use relative to other skills.

• H_a: Some populations (classified by level of project technology) tend to perceive technical competence as more important than others based on extent of use relative to other skills.

TABLE 37

Results of Kruskal-Wallis for Hypothesis #9

Kruskal-Wallis X_1: Project Technology Y_1: Tech Comp in Project Activities

DF	2	
# Groups	3	
# Cases	226	
H	.946	p = .623
H corrected for ties	.988	p = .6101
# tied groups	6	

Kruskal-Wallis X_1: Project Technology Y_1: Tech Comp in Project Activities

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	37	3852	104.108
Group 2	148	17138	115.797
Group 3	41	4661	113.683

Hypothesis # 10. Relative to other skills, acquisition managers in higher technology projects perceive technical competence as more consequential to project success than those acquisition managers in less technical projects.

The Kruskal-Wallis test of Hypothesis #10 evaluated whether populations of acquisition managers defined by different levels of project technology were identical in the perceived importance of technical competence to project success relative to other skills. Table 38 discloses the

results of the test. The following represent the null and alternate hypotheses as restated for the Kruskal-Wallis test of Hypothesis #10:

- H_0: The populations of acquisition managers (classified by level of project technology) are equivalent in the perceived importance of technical competence to project success relative to other skills.

- H_a: Some populations (classified by level of project technology) tend to perceive technical competence as more important to project success relative to other skills than those involved with projects comprising lower levels of technology.

TABLE 38

Results of Kruskal-Wallis for Hypothesis #10

Kruskal-Wallis X_1: Project Technology Y_1: Tech Comp and Project Success

DF	2	
# Groups	3	
# Cases	226	
H	.197	p = .9062
H corrected for ties	.204	p = .9029
# tied groups	6	

Kruskal-Wallis X_1: Project Technology Y_1: Tech Comp and Project Success

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	37	4040	109.189
Group 2	148	16897.5	114.172
Group 3	41	4713.5	114.963

Hypothesis # 11. Acquisition managers across different levels of technical education perceive technical competence equally important.

In testing Hypothesis #11, the Kruskal-Wallis evaluated whether populations of acquisition managers categorized by different levels of technical academic training were identical in the perceived importance of technical competence. Table 39 recounts the test results. The following statements express the null and alternate hypotheses as stated for the Kruskal-Wallis of Hypothesis #11:

- H_0: The populations of acquisition managers (classified by level of technical academic training) are identical in the perceived importance of technical competence.
- H_a: Some populations (classified by level of technical academic training) tend to perceive technical competence as more important.

TABLE 39

Results of Kruskal-Wallis for Hypothesis #11

Kruskal-Wallis X_1: Technical Education Y_1: Technical Competency Importance

DF	4	
# Groups	5	
# Cases	228	
H	11.269	p = .0237
H corrected for ties	12.956	p = .0115
# tied groups	4	

Kruskal-Wallis X_1: Technical Education Y_1: Technical Competency Importance

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	32	4528.5	141.516
Group 2	36	4558.5	126.625
Group 3	59	6827	115.712
Group 4	39	4134	106
Group 5	62	6058	97.71

Hypothesis #12: Figure 27 reveals the relative frequency distribution of responses and Table 40 the statistical test results for Hypothesis #12.

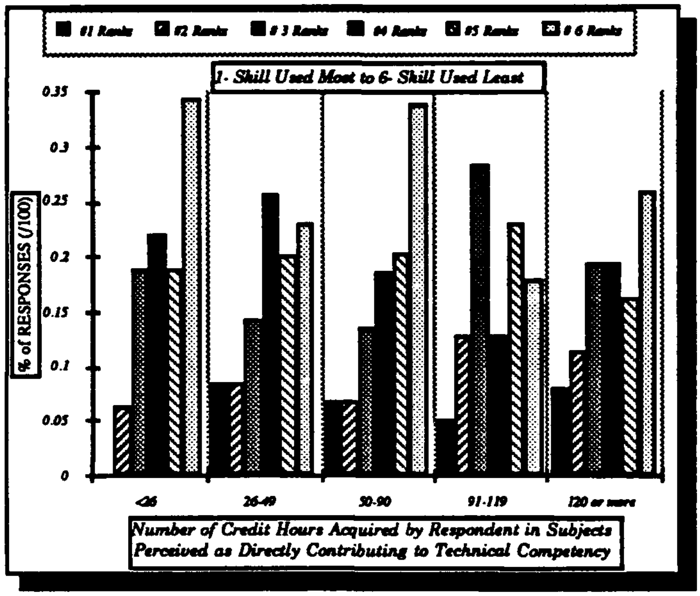

Figure 27. Ranking of Technical Competence Relative to Use Among Other Skills in Project Activities, as a Function of Level of Technical Academic Training: Relative Frequencies.

TABLE 40

Results of Kruskal-Wallis for Hypothesis #12

Kruskal-Wallis X_1: Technical Education Y_1: Tech Comp in Project Activities

DF	4	
# Groups	5	
# Cases	227	
H	5.305	p = .2574
H corrected for ties	5.539	p = .2363
# tied groups	6	

Kruskal-Wallis X_1: Technical Education Y_1: Tech Comp in Project Activities

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	32	4108	128.375
Group 2	35	3852	110.057
Group 3	59	7328.5	124.212
Group 4	39	3926	100.667
Group 5	62	6663.5	107.476

Hypothesis #13. Figure 28 reveals the relative frequency distribution of responses and Table 41 the statistical test results for Hypothesis #13.

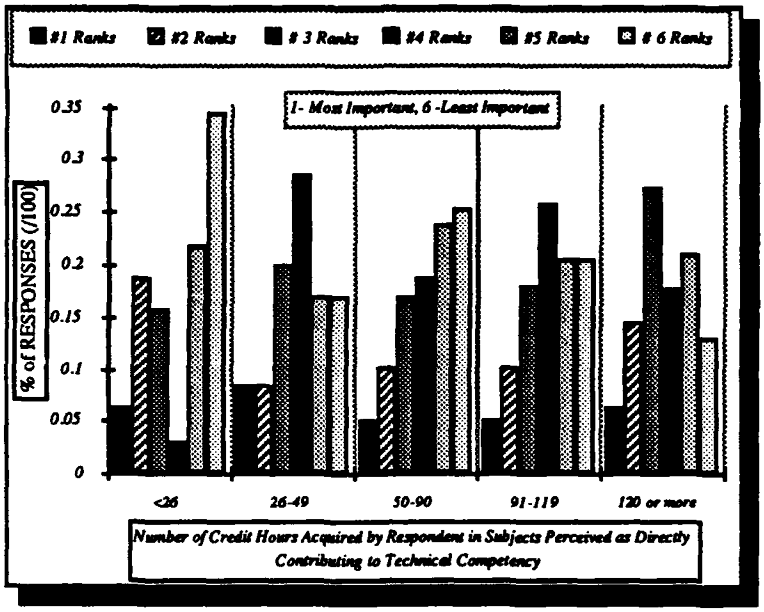

Figure 28. Perceived Importance of Technical Competence to Project Success Relative to Other Skills, as a Function of Technical Academic Training: Relative Frequencies.

TABLE 41

Results of Kruskal-Wallis for Hypothesis #13

Kruskal-Wallis X_1: Technical Education Y_1: Tech Comp and Project Success

DF	4	
# Groups	5	
# Cases	227	
H	4.616	p = .3291
H corrected for ties	4.789	p = .3097
# tied groups	6	

Kruskal-Wallis X_1: Technical Education Y_1: Tech Comp and Project Success

Group:	# Cases:	Σ Rank:	Mean Rank:
Group 1	32	3950.5	123.453
Group 2	35	3820.5	109.157
Group 3	59	7288	123.525
Group 4	39	4559.5	116.91
Group 5	62	6259.5	100.96

Hypothesis # 14. Technical competence is more important to acquisition managers in the early phases of the acquisition process.

The following statements represent the null and alternate hypotheses for the test of this hypothesis:

- H_0: The perceived importance of technical competence is the same for the five phases of the acquisition process.
- H_a: In at least one phase, the perceived importance of technical competence differs significantly compared to the other phases.

Table 42 depicts the Friedman two-way analysis of variance results.

TABLE 42

Friedman two-way analysis of variance results for Importance of Technical Competence Relative to Acquisition Phase: Hypothesis #14

Friedman 5 X variables

DF	4	
# Samples	5	
# Cases	227	
Chi_r-Squared	582.664	p = .0001

Note: 1 case deleted with missing values.

Friedman 5 X variables

Name:	Σ Rank:	Mean Rank:
Concept Exploration & De...	541	2.383
Demonstration & Validation	407	1.793
Engineering & Manufac. ...	497	2.189
Production & Deployment	872	3.841
Operations & Support	1088	4.793

Hypothesis #15. **Acquisition managers perceive personal aptitude for seeking and understanding technical information as the best way to develop technical competency.**

For Hypothesis #15, the Friedman test was used to assess whether differences existed in the perceived importance of various methods of developing technical competency. Figure 29 shows the frequency distribution of responses and Table 43 the statistical test results. The following statements represent the null and alternate hypotheses for the test of Hypothesis # 15:

- H_0: The perceived importance of each of seven methods of developing technical competence is the same.
- H_a: The perceived importance of at least one method differs significantly compared to the others.

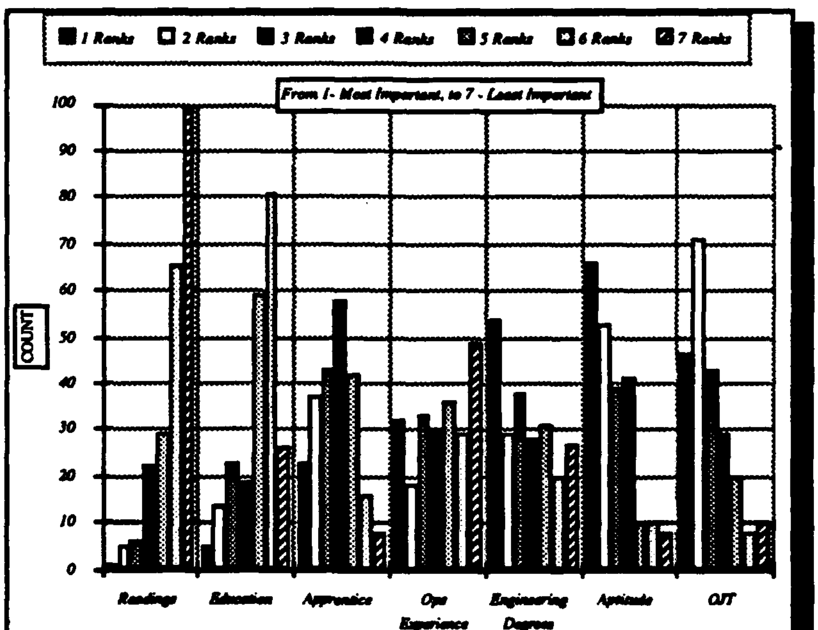

Figure 29. Perceived Importance of Various Means of Developing Technical Competency: Frequency Distributions.

Table A depicts the Friedman two-way analysis of variance results. for this hypothesis.

TABLE 43

Friedman two-way analysis of variance results for Means of Developing Technical Competence: Hypothesis #15

Friedman 7 X variables

DF	6	
# Samples	7	
# Cases	227	
Chi_r-Squared	399.666	p = .0001
Chi corrected for ties	399.76	p = .0001
# tied groups	3	

Note: 1 case deleted with missing values.

Friedman 7 X variables

Name:	Σ Rank:	Mean Rank:
Professional Readings	1345.5	5.927
Other Educational Endea...	1140	5.022
Mentor/Apprenticing	819.5	3.61
Operational Experience	985	4.339
Accredited Engineering D...	802	3.533

Friedman 7 X variables

Name:	Σ Rank:	Mean Rank:
Aptitude for Acquiring Te...	612	2.696
On-the-Job Training	652	2.872

Hypothesis # 16. Acquisition managers with less technical education perceive personal aptitude for seeking and understanding technical information more important in developing technical competency.

• H_0: The perceived importance of "Aptitude..." in developing technical competence is the same among acquisition managers of all levels of technical academic training.

Hypothesis #17. Table 44 reports the descriptive statistics computed to assess the hypothesis on the importance of technical competence to interpersonal skills.

TABLE 44

Results of Kruskal-Wallis for Hypothesis #17

X_1: Importance of Tech Comp to IP Skills

Bar:	From: (≥)	To: (<)	Count:	Percent:	
1	1	2	14	6.195%	
2	2	3	96	42.478%	-Mode
3	3	4	91	40.265%	
4	4	5	22	9.735%	
5	5	6	3	1.327%	

X_1: Importance of Tech Comp to IP Skills

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
2.575	.803	.053	.645	31.197	226
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
1	5	4	582	1644	2
# < 10th %:	**10th %:**	**25th %:**	**50th %:**	**75th %:**	**90th %:**
14	2	2	3	3	4
# > 90th %:	**Mode:**	**Kurtosis:**	**Skewness:**		
3	2	.151	.347		

Hypotheses # 18 and #19. Figure 30 and Figure 31, respectively, describe the frequency distributions of responses applicable to these hypotheses

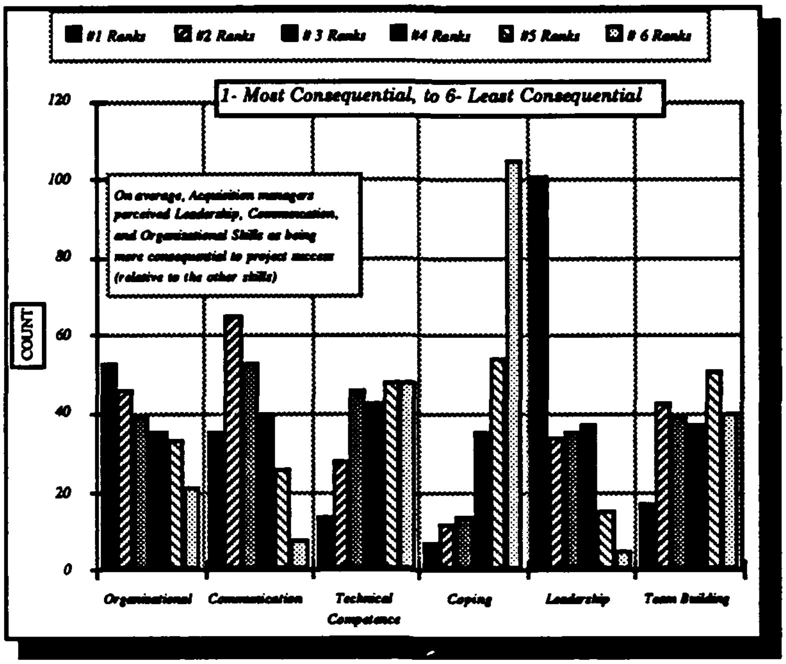

Figure 30. Relative Rankings of Various Skills Based on Perceived Importance to Project Success: Frequency Distributions

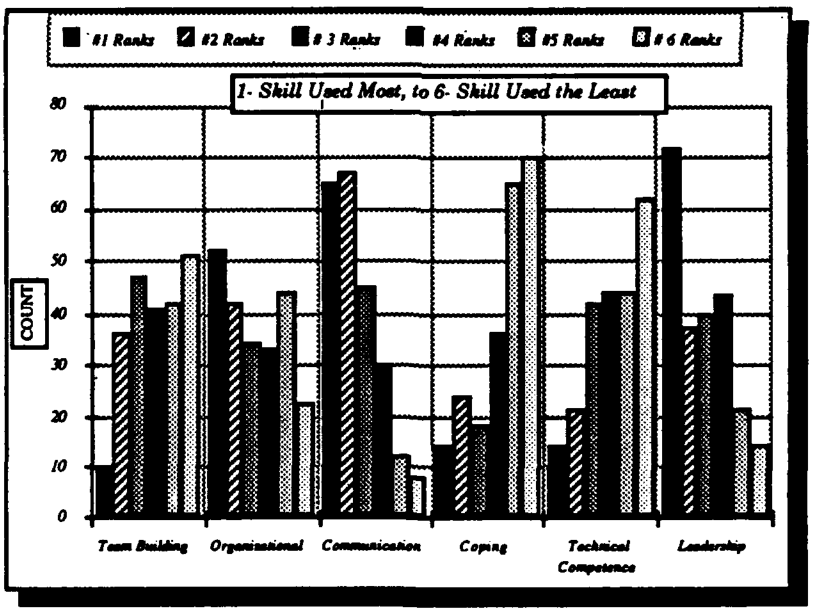

Figure 31. Relative Rankings of Various Skills, Based on Extent of Use in Project Activities: Frequency Distributions

Table 45 and Table 46, respectively, describe the results of the Friedman tests performed to investigate Hypothesis #18 and Hypothesis #19.

TABLE 45

Results of Friedman's Test on Relative Importance of Various Skills to Project Success: Hypothesis # 18

Friedman 6 X variables

DF	5	
# Samples	6	
# Cases	227	
Chi_r-Squared	274.736	p = .0001
Chi corrected for ties	274.771	p = .0001.
# tied groups	1	

Note: 1 case deleted with missing values.

Friedman 6 X variables

Name:	Σ Rank:	Mean Rank:
CO	693	3.053
CA	662	2.916
Tech Comp and Project S...	908.5	4.002
CC	1113	4.903
CL	527.5	2.324

Friedman 6 X variables

Name:	Σ Rank:	Mean Rank:
CB	863	3.802

TABLE 46

Results of Friedman's Test on Relative Importance of Various Skills Based on Extent of Use in Project Activities: Hypothesis # 19

Friedman 6 X variables

DF	5	
# Samples	6	
# Cases	227	
Chi_T-Squared	210.614	p = .0001
Chi corrected for ties	210.641	p = .0001
# tied groups	1	

Note: 1 case deleted with missing values.

Friedman 6 X variables

Name:	∑ Rank:	Mean Rank:
WB	902	3.974
WO	721.5	3.178
WA	562	2.476
WC	1005	4.427
Tech Comp in Project Acti...	949.5	4.183

Friedman 6 X variables

Name:	∑ Rank:	Mean Rank:
WL	627	2.762

Appendix E: Multiple Comparisons for Kruskal-Wallis Tests

MULTIPLE PAIRWISE COMPARISONS for KRUSKAL-WALLIS TESTs
Hypothesis # 5

Category:	Subpopulations:
Importance of Technical Competency	Technical Team Levels

alpha: 0.05

# Groups: 3	# Cases: 228	Mean Ranks:		
Group 1	67	97.112	p-value:	0.001
Group 2	139	126.428		
Group 3	22	92.091	Ssqr:	4351
			Ssqr NTk:	4129
			N-K df:	225
			t (1-alpha/2):	1.96 from table A25 (Conover, 1980)

Test Statistic: 13.5

	Comparison if LHS >	RHS		indicates populations appear different
1 and 2	29.316	18.84	yes	Extremely Good and Reasonably Good
1 and 3	5.021	31.12	no	Extremely Good and So-So
2 and 3	34.337	29.06	yes	Reasonably Good and So-So

MULTIPLE PAIRWISE COMPARISONS for KRUSKAL-WALLIS TESTs
Hypothesis # 11

Category:	Subpopulations:
Importance of Technical Competency	Technical Education Levels

alpha: 0.05

# Groups: 5	# Cases: 228	Mean Ranks		
			Test Statistic:	12.96
Group 1	32	141.516	p-value:	0.012
Group 2	36	126.625		
Group 3	59	115.712	Ssqr:	4351
Group 4	39	106	Ssqr NTk:	4176
Group 5	62	97.71	N-K df:	223
			t (1-alpha/2):	1.96 from table A25 (Conover, 1980)

Pairs:	Comparison if LHS >	RHS		indicates populations appear different
1 and 2	14.891	30.77	no	25 hours or less AND > 25 but < 50
1 and 3	25.804	27.81	no	25 hours or less AND 50 to 90
1 and 4	35.516	30.21	yes	25 hours or less AND > 90 but < 120
1 and 5	43.806	27.57	yes	25 hours or less AND 120 or more
2 and 3	10.913	26.79	no	> 25 but < 50 AND 50 to 90
2 and 4	20.625	29.27	no	> 25 but < 50 AND > 90 but < 120
2 and 5	28.915	26.54	yes	> 25 but < 50 AND 120 or more
3 and 5	18.002	23.04	no	50 to 90 AND 120 or more

Appendix F: Multiple Comparisons for Friedman Tests

MULTIPLE PAIRWISE COMPARISONS for FRIEDMAN TEST
Hypothesis #14

Blocks:
Acquisition Managers

Categories:
Acquisition Phases Ranked by Importance of Technical Competence

alpha: 0.05

# Groups: 5	Rank Σ 227	Mean Ranks
Phase 1	541	2.383
Phase 2	407	1.793
Phase 3	497	2.189
Phase 4	872	3.841
Phase 5	1088	4.793

Test Statistic:	582.66		
p-value:	0.0001		
fac:	20.211		
A2:	12485	k1:	4
B2:	11672	k2:	904

t (1-alpha/2): 2.37 from table A26 (Conover, 1980)
t (1-alpha/2): 1.96 from table A25 (Conover, 1980)

Comparison if	LHS	> RHS	indicates populations appear different	
1 and 2	134	39.6128	yes	Concept Exploration & Definition AND Demonstration & Validation
1 and 3	44	39.6128	yes	Concept Exploration & Definition AND Eng & Manufact Development
1 and 4	331	39.6128	yes	Concept Exploration & Definition AND Production & Deployment
1 and 5	547	39.6128	yes	Concept Exploration & Definition AND Operations & Support
2 and 3	90	39.6128	yes	Demonstration & Validation AND Eng & Manufac Development
2 and 4	465	39.6128	yes	Demonstration & Validation AND Production & Deployment
2 and 5	681	39.6128	yes	Demonstration & Validation AND Operations & Support
3 and 5	591	39.6128	yes	Eng & Manufac Development AND Operations & Support
4 and 5	216	39.6128	yes	Production & Deployment AND Operations & Support

All Phases may be regarded unequal, and technical competence most important in Demonstration and Validation

MULTIPLE PAIRWISE COMPARISONS for FRIEDMAN TEST

Hypothesis #15

Blocks: Acquisition Managers

Categories: Methods of Developing Technical Competence

# Groups: 7	Rank Σ 227	Mean Ranks
Method 1	1345.5	5.927
Method 2	1140	5.022
Method 3	819.5	3.61
Method 4	985	4.339
Method 5	802	3.533
Method 6	612	2.696
Method 7	652	2.872

		alpha:	0.05
Test Statistic:	399.76		
p-value:	0.0001		
fac:	38.776		
A2:	31780	k1:	6
B2:	27289	k2:	1356

t (1-alpha/2): 2.1 from table A26 (Conover, 1980)

t (1-alpha/2): 1.96 from table A25 (Conover, 1980)

if	Comparison LHS	> RHS	indicates populations appear different
1 and 2	205.5	76.0012	yes
1 and 3	526	76.0012	yes
1 and 4	360.5	76.0012	yes
1 and 5	543.5	76.0012	yes
1 and 6	733.5	76.0012	yes
1 and 7	693.5	76.0012	yes
2 and 3	320.5	76.0012	yes
2 and 4	155	76.0012	yes
2 and 5	338	76.0012	yes
3 and 5	17.5	76.0012	no
4 and 5	183	76.0012	yes
5 and 6	190	76.0012	yes
6 and 7	40	76.0012	no

all Methods except 3 and 5 & 6 and 7, may be regarded unequal, and method 6 appears to contribute most to developing technical competence ...aptitude for acquiring and understanding technical information

Method 1 is Professional Readings
Method 2 is Other Educational Endeavors
Method 3 is Mentor/Apprenticing
Method 4 is Operational Experience
Method 5 is Accreditied Engineering Degrees
Method 6 is Aptitude for Acquiring Technical Information...
Method 7 is On-the-Job Training

MULTIPLE PAIRWISE COMPARISONS for FRIEDMAN TEST

Hypothesis #18

Blocks:			Categories:	
Acquisition Managers			Importance of Skills Based on Relative Impact to Project Success	
		Mean		alpha: 0.05
# Groups: 6	Rank Σ 227	Ranks	Test Statistic: 210.64	
Skill 1	693	3.053	p-value: 0.0001	
Skill 2	662	2.916	fac: 34.781	
Skill 3	908.5	4.002	A2: 20657	k1: 5
Skill 4	1113	4.903	B2: 17646	k2: 1130
Skill 5	527.5	2.324		
Skill 6	863	3.802		

t (1-alpha/2): 2.21 from table A26 (Conover, 1980)

t (1-alpha/2): 1.96 from table A25 (Conover, 1980)

Comparison if	LHS	>	RHS	indicates populations appear different
1 and 2	31		68.1702	no
1 and 3	215.5		68.1702	yes
1 and 4	420		68.1702	yes
1 and 5	165.5		68.1702	yes
2 and 3	246.5		68.1702	yes
2 and 4	451		68.1702	yes
2 and 5	134.5		68.1702	yes
3 and 5	381		68.1702	yes
4 and 5	585.5		68.1702	yes
1 and 6	170		68.1702	yes
3 and 6	45.5		68.1702	no
2 and 6	201		68.1702	yes
3 and 4	204.5		68.1702	yes

all Skills except 1 and 2, 3 and 6 may be regarded unequal (significantly different in importance), and skill 5 appears most important in terms of relative impact to project success

Skill 1 is Organizational Skills
Skill 2 is Abilities in Communication
Skill 3 is Technical Competence
Skill 4 is Coping Skills
Skill 5 is Leadership
Skill 6 is Team Building Skills

MULTIPLE PAIRWISE COMPARISONS for FRIEDMAN TEST

Hypothesis #19

Blocks: Acquisition Managers

Categories: Importance of Skills Based on Extent of Use in Project Activities

# Groups: 6	Rank Σ 227	Mean Ranks
Skill 1	902	3.975
Skill 2	721.5	3.178
Skill 3	562	2.476
Skill 4	1005	4.427
Skill 5	949.5	4.183
Skill 6	627	2.762

		alpha:	0.05
Test Statistic:	210.64		
p-value:	0.0001		
fac:	36.054		
A2:	20657	k1:	5
B2:	17422	k2:	1130

t (1-alpha/2): 2.21 from table A26 (Conover, 1980)

t (1-alpha/2): 1.96 from table A25 (Conover, 1980)

if	Comparison LHS	>	RHS	indicates populations appear different
1 and 2	180.5		70.6652	
1 and 3	340		70.6652	
1 and 4	103		70.6652	
1 and 5	47.5		70.6652	
2 and 3	159.5		70.6652	
2 and 4	283.5		70.6652	
2 and 5	228		70.6652	
3 and 5	387.5		70:6652	
4 and 5	55.5		70.6652	
1 and 6	275		70.6652	
3 and 6	65		70.6652	
2 and 6	94.5		70.6652	

all Skills except 1 and 5, 4 and 5, and 3 and 6, may be regarded unequal, and skill 3 appears most important in terms of the time acquisition managers use each in project activities

Skill 1 is Team Building
Skill 2 is Organizational Skills
Skill 3 is Abilities in Communication
Skill 4 is Coping Skills
Skill 5 is Technical Competence
Skill 6 is Leadership

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Vita

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13. ABSTRACT (*Maximum 200 words*)

This research examined the importance Air Force acquisition project managers attribute to technical competence, and several individual and situational factors which might affect their perceptions of the importance of technical competence: extent of acquisition experience, degree of technical academic training, level of project technology, caliber of technical project team, and acquisition phase. A review of the literature revealed that previous studies of project and program managers suffered from several limitations with regard to a direct examination of the importance of technical competence. No single study has empirically supported a clear determination on the importance of this attribute to project managers. Considering the nature of today's projects and the ongoing dramatic rate of technological advancement and change, an investigation of the potential importance of technical competence in managing projects seems particularly critical for prospective project managers and those with little experience. In a study of 228 acquisition managers, the findings show a majority consider technical competence as extremely important or absolutely essential, even though they may rank the attribute low in terms of use when compared to other skills. Further, the results indicate the importance of technical competence among acquisition project managers varies significantly as a function of technical project team capabilities and phase of the acquisition life cycle. In addition, the research suggests technical competence is an important contributor to project managers' ability to communicate. (25)

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